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The sandwich priming paradigm does not reduce lexical competitor effects

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Abstract

We investigated the mechanisms underlying sandwich priming, a procedure in which a brief preprime target presentation precedes the conventional mask-prime-target sequence, used to study orthographic similarity. Lupker and Davis (2009) showed the sandwich paradigm enhances orthographic priming effects: With primes moderately related to targets, sandwich priming produced significant facilitation, but conventional priming did not. They argued that unlike conventional priming, sandwich priming is not susceptible to an uncontrolled counteractive inhibitory process, lexical competition, that cancels out moderate facilitation effects. They suggest lexical competition is eliminated by preactivating the target's representation, privileging the target over similar lexical units (competitors). As such, it better measures orthographic relatedness between primes and targets, a key purpose of many priming studies. We tested whether elimination of lexical competition could indeed account for the observed orthographic priming boost with sandwich priming. In three lexical decision experiments and accompanying simulations with a competitive network model, we compared priming effects in three preprime procedures: no preprime (conventional), identity (target) preprime (sandwich) and competitor preprime (included to exacerbate lexical competition). The related prime conditions consisted of replaced-letters, shared neighbor (one-letter-different from both competitor preprime and target), and transposed-all-letter nonword primes. Contrary to the model's predictions, the competitor preprime did not attenuate (Experiment 1) or even reverse the priming effect (Experiment 2). Moreover, the competitor enabled facilitatory priming that was absent with no preprime (Experiment 3). These data suggested that the

sandwich orthographic boost could not be attributed to reduced lexical competition but rather to prelexical processes in word recognition.

Keywords: visual word recognition; sandwich priming; lexical decision; orthographic similarity; lexical inhibition

Effective reading requires the identification by the reader of the words intended by the writer, in a manner that is invariant or tolerant to sources of variation and distortion related to typeface, size, viewing conditions, perceptual noise, or writer error. It therefore seems reasonable that a variety of candidate matches to a stimulus should be considered or activated, and such a selection of candidates has been proposed from some of the earliest models (e.g., Rubenstein, Garfield, & Millikan, 1970) of lexical access. How candidates are considered and selected is thus central to reading, and several aspects of this process have been subject to recent computational and mathematical modeling efforts (e.g., Adelman, 2011; Davis, 2010; Norris & Kinoshita, 2012).

A core range of evidence for evaluating the proposed processes comes from the masked form priming paradigm developed by Forster and Davis (1984) and first used in the context of lexical selection by Forster, Davis, Schoknecht, and Carter (1987). The ongoing task for the participant is lexical decision on clearly visible letter string targets in capital letters, but each target is preceded by a mask (usually of # symbols) and a prime letter string presented in lower case for a duration that is typically between 15 and 70 ms. One major advantage of this procedure is that due to this brief prime duration, primes are usually not perceived consciously and do not allow for development of strategic responses from the participants. An example sequence of stimuli is thus #####—tible—TABLE. Baseline performance is established on unrelated trials where the prime shares no letters with the target. This can be compared with cases in which the prime shares many features in common with the target, and response times (RTs) are typically reduced when prime and target are similar, an RT priming effect. Different manipulations of the letters of the target to produce the prime (prime types) differ in their similarity to the target, and

their ability to prime the target, apparently in a graded fashion (see Adelman et al., 2014), suggesting that candidates cannot be simply categorically divided into consistent or inconsistent.

A major result established with the masked priming paradigm, for example, is that the presentation of a nonword prime, constructed by replacing one of the target's letters, such as *tible*, produces significantly faster response times in comparison to the unrelated baseline (e.g. Adelman et al., 2014; Forster et al., 1987). This effect is decreased and not always significant when two of the letters are replaced (Lupker & Davis, 2009; Perea & Lupker, 2004). Another finding, demonstrated with the masked-priming methodology reflects the letter position tolerance, rather than letter identity tolerance, of the perceptual system. Perea and Lupker (2003) demonstrated that a prime in which two adjacent letters were transposed (*jugde* from target JUDGE) effected shorter response times than one in which the same letter positions contain two replaced letters as in *jupte*(-JUDGE). This finding has been extended to nonadjacent letter transpositions (e.g., *caniso* - CASINO; Lupker, Perea, & Davis, 2008; Perea & Lupker, 2004). Guerrero and Forster (2008) tested the limits of the letter position tolerance of the visual word recognition system and showed that a priming effect was still observed with primes constructed by adjacent transposition of all the letters in a word except for the external ones (*dsiocnut* – DISCOUNT). However, the priming was no longer significant when the primes were constructed by even more extreme transpositions, such as transposing all the adjacent letters in a word (T-all or transposed-all letter primes; e.g., *avacitno*-VACATION).

The magnitude of the effects produced by form-related masked primes have been interpreted as the degree to which the orthographic codes of the prime and the target match. Thus, results produced with the masked priming paradigm have served as a reference point for evaluating models' predictions regarding the similarity between two strings. One major distinction among theories is how they account for these graded patterns. Adelman (2011) suggests that considered candidates are gradually activated, and candidates are eliminated from consideration as inconsistent features of the stimulus are stochastically perceived. Norris and Kinoshita (2012) posit an explicit Bayesian calculation of the likelihood of percepts (the stimulus perceived with noise) given assumptions about the distributions of words and pseudowords. Approaches based on the interactive-activation model (McClelland & Rumelhart, 1981) suggest that the net input to a word unit weighs positive excitatory and negative inhibitory bottom-up influences in a way that is often summarized as a match score¹. Whether within the interactive-activation framework or not, the predictions and match scores of orthographic encoding models have been compared to empirical results produced with the masked priming methodology that thus served as a validator for the models' credibility.

Although the magnitude of form priming is usually interpreted as the extent to which processing during encoding of the prime and the target overlaps, and an approximate string distance is implied, a limit has been shown in the extent to which a masked form priming effect was obtained: As Lupker and Davis (2009) have emphasized, the priming effect is no longer

¹ Match scores may also reflect only the excitatory bottom-up influences and not the inhibitory ones. In many models, they are perfectly complementary; where they are not, the (asymptotic) net input – reflecting both match and mismatch components – is, of course, the relevant factor.

present when a prime includes more extreme deviations from the target. This introduces a limit of the orthographic priming continuum that is not necessarily present in models' predictions and to an extent is also not consistent with commonsense logic. If the effect of a prime produced by a single transposition of adjacent letters from the target is very similar to that from a prime that is identical (except for case) to the target, it is perhaps, then, surprising that a prime with four such transpositions in an eight-letter target produces no significant priming (Guerrera & Forster, 2008); if copmuter is barely different from COMPUTER, why is ocpmture not still quite similar?

And indeed, Lupker and Davis reported high match scores between transposed all-letter primes and their base words from the relative open-bigram model (Grainger & van Heuven, 2003), the SERIOL model (Whitney, 2001) and previous versions of Davis's spatial coding model (Davis, 1999), suggesting that all those predicted facilitation priming effects, which were not significant in the masked-priming studies of Guerrera and Forster and Lupker and Davis. Likewise, it can be seen as surprising that a prime that matches five out of eight letters of a target produced no priming compared to control (Schoonbaert & Grainger, 2004) given these five matching letters must produce more facilitation than no matching letters, and the three mismatching letters must produce less inhibition than eight mismatching letters.

Lupker and Davis (2009) argued that primes that are moderately related to targets, such as transposed all-letter primes and primes containing replacement of more than two letters, were not able to produce facilitation effects not due to the insufficient orthographic similarity between them and the targets, but due to inhibitory processes that could cancel out facilitation.

The process they have claimed to be responsible is lexical competition, that is, lateral inhibition among word units. Such an inhibitory process is consistent with evidence that word primes that are orthographic neighbors (words of equal length that differ by only one letter in the same position, such as take – cake or take – tape; Coltheart, Davelaar, Jonasson, & Besner, 1977) of targets can produce inhibitory rather than facilitatory priming (e.g., Davis & Lupker, 2006), that words with orthographic neighbors are typically less primeable (e.g., Forster et al., 1987), and that primes that are neighbors of targets are less effective if prime and target share other common neighbors (“shared neighbors”: Van Heuven, Dijkstra, Grainger, & Schriefers, 2001). An example of a shared-neighbor for the prime-target relationship *azound*-*ABOUND* is the word *around*, which is a neighbor of both the prime and the target. Davis (2003) argues that nonword primes, such as *azound* are less effective as they not only preactivate the representation of the target due to form similarity, but also representations of the target’s neighbor, thus introducing competition on the word level that results in suppression of the target’s activation and attenuation of the priming effect.

In the same competitive network framework, Lupker and Davis suggested that primes moderately close to the target were likely to resemble and generate more activation to representations of other lexical units, which once activated would inhibit the target and could cancel out possible facilitation effects which would therefore remain unobserved. In such a lexical competition account, whilst the prime *avacitno* (in *avacitno*-*VACATION*) is reasonably similar to the target *VACATION*, it is more similar to the task-irrelevant word *AVIATION*. The closer neighbor *AVIATION* becomes more activated than *VACATION*, and thus inhibits the word node for *VACATION*, eliminating any possible priming for that target. Lupker and Davis

thus suggested that if lexical competition effects were filtered out, primes moderately related to targets would be able to produce facilitation.

The conventional masked priming paradigm, according to Lupker and Davis (2009), is thus susceptible to counteractive inhibitory processes and therefore is not an appropriate procedure to directly evaluate orthographic encoding schemes. Thus, they explained the absence of these expected facilitatory priming effects by seeking limitations in the methodology that had been used. They sought to design a paradigm that would allow for evaluation of the matches of stimuli that are more distant from the target, by eliminating or reducing lexical competition effects on the target. One route to achieving this requires preventing the activation of non-target words. Lupker and Davis sought to do so by taking advantage of lexical competition by pre-activating the target, by presenting it for a short duration. The pre-activated target then itself inhibits potential competitors and so is not subject to inhibition itself. That is, a possible stimulus sequence is #####—VACATION—avacitno—VACATION, which was termed a sandwich prime because the prime is sandwiched between two presentations of the target. Simulations of an otherwise unpublished hybrid of spatial coding and interactive activation models gave the prediction that AVIATION would no longer become active, and in the absence of such lexical competition, the target activation of VACATION at the end of the prime stimulus was not at floor. Instead, the target activation was driven by the match score of prime and target so that priming was now predicted for the transposed all-letters prime relative to control.

Lupker and Davis (2009) confirmed this prediction empirically in their first experiment: In the sandwich priming paradigm, the transposed all-letters prime produced shorter response times

than an unrelated (sandwiched) prime; in contrast, the non-sandwiched version showed no priming relative to the non-sandwich control. In their second experiment, they extended the finding to the case of primes with several replaced letters, with a parametric manipulation of number of replaced letters from one through five in a seven-letter target. In the standard non-sandwiched case, priming was shown only for one- and two-letter-different primes. In the sandwiched case, priming was greater for one- through three-letter-different primes, so that priming for the three-letter different case was significant. These data patterns were indeed consistent with Lupker and Davis's (2009) lexical inhibition account. The authors interpreted the results as an evidence that the sandwich priming procedure successfully eliminated lexical competition effects and as such it overcame certain limitations of the original masked priming and was a better tool for evaluating orthographic input coding models. For these reasons, the sandwich priming procedure has already been employed in several studies researching orthographic processes so far (e.g. Ktori, Grainger, Dufau, & Holcomb, 2012; Ktori, Kingma, Hannagan, Holcomb, & Grainger, 2014; Lupker, Zhang, Perry, & Davis, 2015).

The present study aimed to test Lupker and Davis's (2009) interpretation that the enhanced form priming effects produced with the sandwich priming paradigm were due to the elimination of lexical competition processes. Although the explanation of Lupker and Davis is consistent with their data, other processes might instead be responsible for the obtained results. A possible alternative explanation is that the results were driven by lower-level bottom-up processes that do not reflect lexical stages and lexical competition in particular. As there is an additional brief presentation of a prime, extra complexity is added in the sandwich priming procedure and the mechanisms that underlie the processing of two masked primes are not

entirely transparent. The additional initial letter string – the *preprime* – is another brief visual event that provides additional processing information and its presentation prolongs the time until the presentation of the target. It is not exactly clear what the interaction is between the prime and preprime and whether the same mechanisms are involved and just multiplied by two in a sequential presentation of two brief primes and in a presentation of a single brief prime, immediately followed by the target.

As we consider the data provided by Lupker and Davis (2009) to be inconclusive for the determination of the nature of the responsible processes, we designed several experiments that aimed to provide further evidence of whether the enhanced form priming effects were caused by the modulation of lexical competition mechanisms or not. The way we chose to do that was by following the interactive activation framework and retaining lexical competition by presenting lexical competitor of the target as a preprime, rather than an identical stimulus. If primes can be ineffective due to the role of lexical inhibition – and preprimes can modulate lexical inhibition – as Lupker and Davis propose, then the pre-activating a competitive alternative should exacerbate inhibition, which should if anything further attenuate priming effects. In contrast, if a presentation of a stimulus that resembles both the related prime and the target does not produce any particular reduction in the strength of priming or indeed increases it, this would provide some evidence that the results obtained with a sandwich priming were not caused by reduction of lexical competition effects, but rather by some other mechanism, such as prelexical bottom-up processes.

The present work consists of three experiments in total, as well as corresponding simulations of these experiments. The simulations were run with the Spatial Coding Model (Davis, 2010). This model represents a more recent version of the competitive network system, used for the simulations in the study of Lupker and Davis (2009). The model is based on the interactive activation model (McClelland & Rumelhart, 1981), but has a different implemented encoding scheme. In the interactive activation's slot-based encoding scheme, two letters with the same letter identity are treated as different letters if they are in different positions and therefore *jugde* is as similar to *judge* as is *jupte*. The Spatial Coding Model, however, could account for transposed-letter effects with its two-dimensional spatial coding scheme, in which letter position and identities are encoded as spatial patterns of values.

The computational modelling methodology could provide an insight as to how the lexical inhibition elimination account of sandwich priming, suggested by Lupker and Davis, fits the specific prediction of the model, regarding the effect of a competitor preprime, based on the properties of the stimuli, such as frequencies and orthographic neighborhoods of the preprimes, primes and targets. The model's predictions and the lexical inhibition account of the sandwich priming effects could then be evaluated by a comparison with the observed empirical data.

The nature of the sandwich priming effects was explored in the context of Lupker and Davis's (2009) Experiment 2 stimuli with replaced-letter primes (Experiment 1), and new stimuli with shared-neighbor primes (Experiment 2) and transposed-all letter primes (Experiment 3).

Experiment 1

Our initial examination of the question was based on the stimuli used in Lupker and Davis's (2009) Experiment 2 to maintain continuity with the original work.

Method

Participants

Ninety students or members of staff from the University of Warwick took part in the experiment. All reported English as their native language. They either received course credit or were paid £3 for their participation.

Design

Three preprime types (none, identity, competitor), that generated three different procedures — conventional masked priming, sandwich masked priming and competitor-modified-sandwich masked priming — were crossed with six prime types (1-, 2-, 3-, 4-, and 5-letters different, and all-letter different control) within-subjects. Counterbalancing was performed by first dividing the items into three equal different preprime type trials for words and nonwords respectively. These comprised of 20 trials per preprime type per target type (each set taken consecutively from the stimulus list of the original paper). The preprime conditions were then counterbalanced in three lists. Each of these lists was transformed into six different versions for the counterbalancing of the prime type conditions. In these lists, the six levels of the prime type were cycled (one-by-one in the order of targets in the original stimulus list). The levels of the two factors appeared equal times in each of the lists. Each of the eighteen resulting conditions appeared either 3 or 4 times in a list for each target type, but the total frequency of the

conditions was equalised over all the counterbalancing lists, as every combination of preprime type, prime type and target item appeared exactly once across the eighteen lists. All trials were newly randomly intermixed for each participant².

Stimuli

The 60 seven-letter words and 60 matched pseudoword foils were taken from Lupker and Davis's (2009) Experiment 2, along with their primes. The mean frequency reported by the authors was 53.1 per million (CELEX; Baayen, Piepenbrock, & van Rijn, 1993; range 20–145). The mean SUBTLEX-UK Zipf frequency was 4.45 (range 2.79 - 5.2; Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). The mean neighborhood size (number of orthographic neighbors, Coltheart N; Coltheart et al., 1977) was 0.3 (range 0 – 2). These were augmented with the competitor stimulus for each word, which was selected to be the seven-letter word with the least string edit distance (the number or cost of operations to transform one string to another) to the target, using a modified edit distance designed to reflect empirical results from priming³ (e.g., PROTECT for PROJECT, or HALFWAY for HOLIDAY). The mean CELEX frequency of the competitor words was 9.14 per million (range 0.34 – 216.54). The mean SUBTLEX-UK Zipf frequency was 3.13 (range 1.47 – 5.14). The mean neighborhood size was 0.47 (range 0 – 5). Neighborhood size and CELEX frequency properties were obtained with N-Watch (Davis, 2005). The CELEX frequency of the competitor was higher than the target in only 3 out of the 60 target-competitor pairs, two of which had also a higher SUBTLEX-UK Zipf frequency. A non-

² DMDX scripts for all experiments are made available at: <http://adelmanlab.org/sandwich/>.

³ In particular: The cost of an internal replacement was 1, the cost of an initial replacement was 6, the cost of a final replacement was 5, and the cost of the first internal transposition was 1.

identical pseudoword was constructed for each foil by altering one letter to act as a competitor preprime for the nonword trials. The preprime for the sandwich priming condition in the nonword trials was the nonword foil. The prime conditions in the nonword trials matched those in the word trials and comprised of primes that differed from the nonword foils by one, two, three, four, five and seven letters. All stimuli for this experiment are listed in Appendix A.

Procedure

Participants were instructed that their task was to identify whether stimuli presented in capital letters were real English words or nonsense words, indicating the former by pressing the yes key (the right shift key labeled as such) or the no key (the left shift key labeled as such). The experimental trials were preceded by ten practice trials, after which participants were given the opportunity to ask for clarification. On each trial, a ##### mask in 20-point Courier New was presented for 500ms. When the preprime was identity (the original sandwich priming), the target stimulus was then presented at 7.5-point size for 33ms. When the preprime was competitor (the new modified-competitor sandwich priming), the competitor was then presented at 7.5-point size for 33ms. When there was no preprime (conventional masked priming), presentation proceeded immediately from the mask to the prime. The prime was presented for 50ms at 12.5-point size. The target was then presented at 20-point size until the participant responded or 2000ms had elapsed. Feedback was given after every trial. The paradigms for this and subsequent experiments were approved by the University of Warwick Department of Psychology Research Ethics Committee on its delegated authority for student projects.

Results

Response Time

Data analyses were performed with the packages *lme4* (Bates, Maechler, Bolker, & Walker, 2015), *car* (Fox & Weisberg, 2011) and *phia* (De Rosario-Martinez, 2013) as implemented in R version 3.4.1 (R Core Team, 2017). In this and the subsequent analyses, linear mixed-effects models were initially fitted with their full random structure and were later simplified in the cases in which they failed to converge (Barr, Levy, Scheepers, & Tily, 2013).

Mean response times and error rates for word trials in Experiment 1 are shown in Table 1. Trials with response times shorter than 150 ms or longer than 1500 ms were excluded from the latency analyses⁴, as were incorrect trials. A linear mixed-effects model was fitted with preprime type, prime type and their interaction as fixed factors. By-subject and by-items intercepts and slopes for preprime type and prime type were added as random factors. Type II Wald chi-square tests were performed on the fitted model to establish the significance of the fixed main effects as well as their interaction. The results revealed a main effect of prime type, $\chi^2(5) = 80.076$, $p < .001$; and a significant interaction between prime type and preprime type, $\chi^2(10) = 19.957$, $p = .03$. The effect of preprime type was not significant, $\chi^2(2) = 3.47$, $p = .176$. Looking at pairs of preprime types, the preprime by prime interaction was only significant for the comparison of the identity and no preprime conditions, $\chi^2(5) = 15.357$, $p = .009$. Examination of Figure 1 clearly shows that

⁴ These data, and analogous data of subsequent experiments, are available at <http://adelmanlab.org/sandwich/>.

this must be driven by greater priming in the identity (sandwich) condition than the no-preprime (conventional) condition. The priming in the competitor condition differed significantly from neither, $\chi^2(5) = 8.937, p = .112$, vs. identity, and $\chi^2(5) = 5.616, p = .345$, vs. no preprime. To investigate the priming effect further, we constructed post-hoc contrasts for each of the related prime conditions. We used the Benjamini & Yekutieli (2001) adjustment method to control false discovery rate.

One-letter-different primes Comparing only one-letter-different and control (all-letter-different primes), the interaction with prime type showed differential priming, $\chi^2(2) = 9.433, p = .009$. This priming was 59 ms in the identity condition, 41 ms in the competitor condition, and 24 ms in the no-preprime condition, all of which were significant, $\chi^2(1) = 46.353, p < .001$; $\chi^2(1) = 20.702, p < .001$; $\chi^2(1) = 7.028, p = .015$, respectively. Contrasts between the priming in each two of the preprime conditions showed that the priming in the identity preprime condition differed significantly from the priming in the no preprime condition, $\chi^2(1) = 9.418, p = .012$, but not from the priming in the competitor condition, $\chi^2(1) = 2.726, p = .271$, which also did not differ significantly from the priming in the no preprime condition, $\chi^2(1) = 1.99, p = .29$.

Two-letter-different primes Priming of 42 ms for the identity condition was significant, $\chi^2(1) = 23.296, p < .001$. The 21 ms priming effect in the competitor condition and the 17 ms priming effect in the conventional no-preprime condition were marginally significant, $\chi^2(1) = 5.515, p = .052$; $\chi^2(1) = 4.324, p = .069$. These priming effects did not differ significantly, interaction $\chi^2(2) = 4.996, p = .082$.

Three-letter-different primes When the prime was three-letter different, it produced significant facilitation relative to the control only in the identity preprime condition: $\chi^2(1) = 16.777, p < .001$. It was not significant in the no preprime condition, $\chi^2(1) = 2.59, p = .296$, nor in the competitor preprime condition, $\chi^2(1) < 1$.

Four- and five-letter-different primes The effect of the four-letter and five-letter different primes was not significant in any of the preprime conditions, and there were no interactions between prime type and preprime type.

Accuracy

A generalized linear mixed-effects model with binomial distribution was fitted for the word accuracy analyses with prime type, target type and their interaction as fixed factors and by-subjects and by-items intercepts and slopes for preprime type as random factors. The effect of prime type was significant, $\chi^2(5) = 12.383, p = .03$. The accuracy of the participants decreased with the increase of the number of replaced letters in the primes.

Nonword Data

Response Time Mean response times and error rates for nonword trials in Experiment 1 are shown in Table 2. Trials with response times shorter than 150 ms or longer than 1500 ms were excluded from the latency analyses. A linear mixed-effects model was fitted with preprime type, prime type and their interaction as fixed factors and by-subject and by-items intercepts and slopes for preprime type as random factors. The results showed a main effect of preprime type, $\chi^2(2) = 8.938, p = .011$. The effect was driven by the significant difference between the

identity preprime condition and the no preprime condition, $\chi^2(1) = 8.96, p = .003$. Overall, participants were significantly faster when the target foil was presented as a preprime than when there was no preprime.

Accuracy A generalized linear mixed-effects model with binomial distribution was fitted with prime type, target type and their interaction as fixed factors and by-subjects and by-items intercepts and slopes for preprime type as random factors. The interaction between preprime type and prime type was significant, $\chi^2(10) = 29.048, p = .001$. Post-hoc contrasts with Benjamini & Yekutieli (2001) adjustment for the one-letter-different prime type and the all-letter-different prime type as a control showed a significant facilitation only in the identity preprime condition, $\chi^2(1) = 8.91, p = .016$. Contrasts between the priming in each two of the preprime conditions showed that the priming in the identity preprime condition differed significantly from the priming in both competitor preprime condition, $\chi^2(1) = 12.264, p = .003$, and no preprime condition, $\chi^2(1) = 5.737, p = .046$. As could be observed in Table 2, however, the pattern of results did not exhibit a consistent structure that could lead to a straightforward interpretation. A difference in priming between the identity preprime and the competitor and no preprime conditions was also observed in the five-letter-different prime condition, $\chi^2(1) = 9.475, p = .006$; $\chi^2(1) = 11.872, p = .003$, in which the accuracy of participants in the identity preprime condition increased in comparison to the more related prime conditions.

Simulation of Experiment 1

Method

Each of the simulations in the present work was run on the same word trials stimuli as the ones in the corresponding experiment. The *easyNet* simulation software (<http://adelmanlab.org/easyNet/>) was used for all the simulations. A vocabulary of 30606 words from the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993) was loaded in the Spatial Coding Model (Davis, 2010). The model was tested with its default parameters.

The procedure of the conventional masked priming included a presentation of the prime for 50 cycles, followed by the presentation of the target. The sandwich priming procedures were identical, except for the 33 cycles presentation of the preprime (either the target itself or the “competitor” word orthographically related to the target) before the prime. As the response time in the model was measured from the onset of the first priming event, the value of 50 was subtracted from the response times in the no preprime trials and the value of 83 was subtracted from the response times in the sandwich priming trials. The resulting value therefore represented the response time from the target onset until the response.

Results

The model recognized correctly all the target stimuli as words. As in the Lupker and Davis (2009) study, we will focus on the pattern predicted by the model, rather than on the results of statistical analyses as the model’s response times do not include participant variability and therefore numerically small differences produce statistically significant results. Following Davis’s (2010) calibration of parameters, we consider one cycle priming effect to be comparable to 1 ms priming.

As previously, the model predicted a priming boost in the identity preprime (original sandwich priming) condition in which the target was presented before the prime, relative to the no preprime condition. In the one, two and three -letter different priming conditions, the model predicted a priming effect of 49, 36 and 22 cycles, respectively. In the no preprime condition, the predicted priming effect for the same priming conditions was 29, 11 and 3 cycles, respectively. Thus, the model fitted the portion of the experiment that was a (within-subject mixed-list) replication well. However, as can be observed in the right panel of Figure 1, the presentation of a competitor preprime attenuated the priming effect, relative to the no preprime condition. The predicted priming after the presentation of a competitor preprime was consistently smaller than the priming effect in the no preprime condition. In the one, two and three-letter different priming conditions, the effect was decreased to the values 16, 2 and -2 cycles.

Discussion

The response time results of Experiment 1 demonstrated the expected sandwich priming boost of the orthographic priming effect evident in the significantly larger priming that was observed when the target was presented before as a preprime, than when the original masked priming paradigm was employed. Apart from producing a bigger size of the effect, the presentation of the target before the prime led to a significant priming effect in the three-letter different prime condition that was not observed in the no preprime condition. These results replicated those reported by Lupker and Davis (2009) and matched the prediction of the Spatial Coding Model. However, contrary to the model's predictions and the hypothesis that a preprime presentation

addresses lexical competition effects, the presentation of the competitor preprime did not attenuate the priming effect relative to the one observed in the no preprime condition. As the priming effect of the one-letter different condition did not differ significantly between the identity and the competitor conditions, but only between the identity and the no preprime conditions, if anything, there was a trend of the competitor preprime towards producing a slight boost, rather than attenuating the priming effect.

Experiment 1 gave no evidence that lexical competition could eliminate priming when an attempt was made to inject lexical competition with an initial prime that was the closest competitor of the target. However, the absence of inhibitory effect might be attributed to the distance of preprimes to targets, because Lupker and Davis (2009) chose many targets that had no one-letter-different neighbors. Therefore, as potential competitors, they might have been ineffective because they were not sufficiently supported by the subsequent presentations of the prime and the target or because only near neighbors have inhibitory links (cf. Davis & Lupker, 2006). In interactive-activation-based models (McClelland & Rumelhart, 1981), such as the Spatial Coding Model (Davis, 2010), nodes representing words very similar to targets, such as target's orthographic neighbors, receive more activation upon target's presentation as more letter nodes consistent with the input receive excitation and feedforward to competitor word nodes. The higher the activity level of a word node, the stronger the inhibitory effects it produces on other word nodes. As the primes in Experiment 1 were constructed by replacing letters from targets and targets were in most of the cases more than one-letter-different from the competitors, the activity of the competitor word node could have dropped after the presentation of the prime and subsequently of the target, resulting in a weaker influence of the

competitor preprimes. Figure 2 confirms this concern and illustrates how the activity of the competitor word node could not be sustained by the prime and dropped with its presentation after the 33th cycle in a trial example from the simulation of Experiment 1. Conversely, as the prime was a target-only neighbor, the activity of the target node rapidly increased with the prime presentation. The time the target needed to reach a recognition threshold was thus not dramatically delayed by the preprime presentation of the competitor. This example indicates that the distance between the competitor and the prime and between the competitor and the target could partially explain the preserved facilitation pattern in the competitor preprime condition in Experiment 1 and the lack of a reversed priming effect in the simulation of Experiment 1.

Another reason of the lack of inhibitory effects in the competitor preprime condition might concern the relative frequency of competitors and targets. As Lupker and Davis's (2009) stimuli included high frequency targets, only in 5% of the competitor-target pairs was the competitor a more frequent word than the target. In interactive-activation terms, higher frequency words have higher resting levels, therefore reach positive activation levels sooner, and therefore produce more inhibition to other word nodes. This hypothesis has been supported by evidence from previous studies demonstrating that higher frequency target neighbor word primes produce stronger inhibitory effects than lower frequency ones (Davis & Lupker, 2006; Segui & Grainger, 1990).

The results of Experiment 1 showed no signs of inhibitory effects produced by the competitor preprime. There is a possibility that these results could be attributed to the properties of the

stimuli and the low competitiveness of the competitors. Partially, this interpretation is supported by the results of the simulation, which demonstrated inhibitory influence and attenuated facilitation effect in the competitor preprime condition, however, did not indicate a reversal of the priming effect as a prediction of the model. An important question arises at this moment. If we accept that words closest in form to targets are their strongest competitors, and that the competitors in Experiment 1 are not inhibitory enough, then we should accept that the targets in Experiment 1, with their low neighborhood density properties, high word frequencies and lack of high frequency neighbors, are not prone to the influence of a strong lexical competition. If this is the case, why would the large priming boost produced with the original sandwich priming paradigm with these stimuli be attributed to a decreased lexical competition? We continue our investigation of the nature of the sandwich priming effects with a selection of new stimuli.

Experiment 2

Experiment 2 addressed the aforementioned concerns regarding the similarity among stimuli by using only stimuli that were one letter different from each other. That is, primes were Coltheart neighbors of targets (e.g. azound - ABOUND) and potential competitors were Coltheart neighbors of both, that is, shared neighbors (e.g. AROUND-azound-ABOUND). Prior research has found that prime-target combinations for which such shared neighbors exist are less effective (Davis & Lupker, 2006; Van Heuven et al., 2001). Moreover, to enhance the scope for inhibition, the potential competitor was chosen to be of higher frequency than the target

(Davis & Lupker; Segui & Grainger, 1990). In interactive-activation framework (McClelland & Rumelhart, 1981), the high-frequency neighbor competitor should get activated more rapidly than a low frequency word due to its higher resting level and its activation levels should increase dramatically after the presentation of the neighbor prime and the neighbor target, eventually resulting in suppressing the target's activity through inhibitory lateral connections. The expectation is, that if the preprime presentation in a sandwich priming paradigm affects lexical competition, such a strong competitor should reverse or at least decrease the facilitation effect that would be observed with the conventional masked priming paradigm.

Method

Participants

One hundred eighteen native English speakers took part in this experiment. They were undergraduate students at the University of Warwick and received course credit for their participation. The last four participants were replacements for those with low accuracy scores (correct on less than 75% of the trials), leaving data from 114 for analysis.

Design

The three types of preprime type (identity, competitor, none) were crossed within-subjects with prime relatedness, with the related prime type being shared neighbor. The six conditions were rotated over the targets to produce six counterbalancing lists. All trials were randomly intermixed anew for each participant.

Stimuli

Seventy-eight six-letter words with higher frequency neighbors were chosen as word targets. They had a mean CELEX frequency of 3.69 per million (range 0.56 - 15.87), mean SUBTLEX log frequency Zipf 3.18 (range 1.47 – 4.22) and only one Coltheart neighbor that was used as a competitor preprime. The targets' neighbors had higher frequencies than the targets. Their mean CELEX frequency was 26.751 per million (range 1.01 - 503.41), mean SUBTLEX log frequency Zipf 3.83 (range 2.11 – 5.86); mean neighborhood size 2.27 (range 1 – 9). A shared neighbor pseudoword was constructed for each preprime condition to be the related prime for these stimuli.

Seventy-eight further six-letter words were chosen to be the “competitor” preprimes of the nonword foils; nonword foils were constructed by changing one letter of these; and shared neighbor primes were constructed by changing that letter again. Unrelated primes were constructed for each preprime condition by randomly selecting six letters without replacement that were in neither competitor nor target. The nonword foils served as preprimes in the identity preprime condition, nonword trials. All stimuli for this experiment are listed in Appendix B.

Procedure

The procedure was identical to that of Experiment 1.

Results

Response Time

Trials in which the response took less than 150 ms or longer than 1500 ms or was incorrect were excluded from the response time analyses.⁵ Mean response times and error rates by condition for word trials are displayed in Table 3. A linear mixed-effects model was fitted with preprime type, prime type and their interaction as fixed factors. The random effects ultimately included in the model were the by-subject and by-items intercepts and slopes for preprime type and prime type, as well as the by-items slopes for their interaction. The effect of prime type was significant $\chi^2(1) = 62.404, p < .001$. The effect of preprime type was not significant, $\chi^2(2) = 3.74, p = .154$, nor was the interaction between preprime type and prime type, $\chi^2(2) = 1.59, p = .451$. The difference between the unrelated and related primes was significant in all preprime conditions: identity, $\chi^2(1) = 25.923, p < .001$; competitor, $\chi^2(1) = 28.888, p < .001$; no preprime, $\chi^2(1) = 15.34, p < .001$.

Accuracy

A generalized linear mixed-effects model with binomial distribution was fitted for the word accuracy analyses with preprime type, prime type and their interaction as fixed factors and by-subjects and by-items intercepts and slopes for preprime type, prime type and their interaction as random factors. The effects of preprime type and prime type were both significant, $\chi^2(2) = 8.402, p = .015$; $\chi^2(1) = 8.498, p = .004$. The interaction between the two factors was not significant, $\chi^2(2) = 3.389, p = .183$. In general, participants made significantly fewer errors in the no preprime

⁵ In addition, data from the words *navels*, *quotas*, *usable*, *rectal*, *sulked*, *convex* in Experiment 2 and *navels* and *portly* in Experiment 3 were excluded from the analyses as the accuracy of those items was less than 60%.

condition than in the identity preprime, $\chi^2(1) = 5.496$, $p = .019$, and in the competitor preprime conditions, $\chi^2(1) = 6.14$, $p = .013$. They were also significantly more accurate when the prime was related than when it was unrelated, $\chi^2(1) = 7.957$, $p = .005$.

Nonword Data

Response Time Mean response times and error rates for nonword trials in Experiment 2 are displayed in Table 4. Trials with response times shorter than 150 ms or longer than 1500 ms were excluded from the latency analyses. In addition, items with accuracy less than 60% were not included in the analyses. A linear mixed-effects model was fitted with preprime type, prime type and their interaction as fixed factors and by-subject and by-items intercepts and slopes for preprime type and prime types as random factors. The results revealed a main effect of preprime type, $\chi^2(2) = 9.037$, $p = .011$. The effect was driven by the significant difference between the identity preprime condition and the condition with no preprime, $\chi^2(1) = 9.012$, $p = .003$. Participants were faster to reject nonword foils when the foils were presented as preprimes than when there were no preprimes.

Accuracy A generalized linear mixed-effects model with binomial distribution was fitted with preprime type, prime type and their interaction as fixed factors and by-subjects and by-items intercepts and slopes for preprime type, prime type and their interaction as random factors. The results revealed a significant interaction between preprime type and prime type, $\chi^2(2) = 8.891$, $p = .012$. The difference between the unrelated and related prime conditions was significant only when there was no preprime, $\chi^2(1) = 8.655$, $p = .003$. In this preprime condition, participants were significantly more accurate after a related prime, than after an unrelated one.

Simulation of Experiment 2

Experiment 2 was simulated with the same method as for Experiment 1. The model recognized correctly all the target stimuli as words. Mean predicted response times (cycles) are included in Table 3. The model predicted a small facilitation priming of 3 cycles in the no preprime condition, thus underestimating the effect in comparison to the empirical results. This priming effect was enhanced significantly in the identity preprime, in which it was 37 cycles, matching the size of the one observed in the human data. Critically, the model predicted a strong inhibitory effect (-42 cycles) in the competitor preprime condition.

Discussion

The results from Experiment 2 showed no sign of inhibitory effect as a result of the high frequency neighbor presentation before the prime. There was a significant facilitatory priming effect in the competitor preprime condition that was numerically bigger than the priming effect in the no preprime condition. These results contrasted the prediction of the Spatial Coding Model (2010) of a strong inhibitory effect in the competitor preprime condition and the claim that the preprime presentation addresses counteractive inhibitory effects produced by lexical competition (Lupker & Davis, 2009). As the prediction of the model in the simulation of Experiment 2 was specific to the stimuli of Experiment 2, it verified the strong competitive

environment with these items in the competitor preprime condition, according to the interactive-activation account.

Experiment 3

In Experiment 3, we sought to extend the results of Experiment 2 to the case of transposed-all primes, which were the other motivating case for the development of sandwich priming. As previous studies have shown no significant priming effect of transposed-all letter primes relative to control when the conventional masked priming paradigm was used (Guerrera & Forster, 2008) and significant facilitation effect with the sandwich priming paradigm (Lupker & Davis's, 2009, Experiment 1), a comparison between these two procedures and a competitor sandwich would be informative of the mechanisms triggered by the additional presentation of a preprime. If a significant facilitation effect could be obtained with transposed-all primes and a competitor preprime, that could be considered as evidence that a preprime related to the target acted as an attenuated version of a sandwich prime and did not affect lexical competition processes. If, on the contrary, such a presentation reversed the direction of the effect and led to inhibitory effect on the target recognition, that would provide a strong evidence towards a lexical competition account of sandwich priming.

Method

Participants

Sixty-five undergraduate students from the University of Warwick took part in the experiment for course credit. All of them reported English as their native language. Participants who were accurate in less than 75% of the trials (5 people) were replaced, so data from 60 were analysed.

Stimuli

The stimuli were the same as those in Experiment 2, except the shared neighbor prime was replaced with the transposed-all prime (e.g., lbaehc-BLEACH) and the randomly generated unrelated primes were resampled. All stimuli for this experiment are listed in Appendix C.

Procedure

The procedure was the same as Experiments 1 and 2.

Results

Response Time

Word trials with incorrect responses and those with response times shorter than 150 ms or longer than 1500 ms were excluded from the RT analysis. Mean response times and error rates by condition are shown in Table 5. A linear mixed-effects model was fitted with preprime type, prime type and their interaction as fixed factors. The full random structure was successfully included in the model. The random effects were the by-subject and by-items intercepts and slopes for preprime type, prime type and their interaction. The effect of prime type was significant $\chi^2(1) = 23.759, p < .001$. The interaction between preprime type and prime type was also significant $\chi^2(2) = 13.042, p = .001$. The effect of preprime type was not significant, $\chi^2(2) =$

2.731, $p = .255$. The interaction was driven by the significantly greater facilitatory priming effect produced in the two sandwich conditions in comparison to the one produced in the no preprime condition. Contrasts between the preprime conditions showed that the difference between the priming in the identity preprime condition and the no preprime condition was significant, $\chi^2(1) = 4.965$, $p = .026$, as was the difference between the competitor preprime and the no preprime condition $\chi^2(1) = 12.93$, $p < .001$. The difference between the identity preprime condition and the competitor preprime condition was not significant $\chi^2(1) = 1.673$, $p = .196$. Pairwise comparisons between the two priming conditions for each of the preprime conditions showed that the difference between the unrelated and related primes was significant in the identity preprime condition, $\chi^2(1) = 13.272$, $p < .001$; and in the competitor preprime condition, $\chi^2(1) = 31.201$, $p < .001$; but not in the no preprime condition, $\chi^2(1) < 1$.

Accuracy

A generalized linear mixed-effects model with binomial distribution was fitted for the word accuracy analyses with preprime type, prime type and their interaction as fixed factors and by-subjects and by-items intercepts and slopes for preprime type as random factors. The effect of prime type was significant, $\chi^2(1) = 16.89$, $p < .001$. Participants were significantly more accurate when the prime was related than when it was unrelated.

Nonword Data

Response Time Mean response times and error rates for nonword trials in Experiment 3 are displayed in Table 6. Trials with response times shorter than 150 ms or longer than 1500 ms were excluded from the latency analyses. In addition, items with accuracy less than 60% were

not included in the analyses. A linear mixed-effects model was fitted with preprime type, prime type and their interaction as fixed factors and by-subject and by-items intercepts and slopes for preprime type, prime types and their interaction as random factors. The effect of prime type was significant, $\chi^2(1) = 4.097, p = .043$. Participants were faster to reject nonword foils when the primes were related, than when the primes were not related.

Accuracy A generalized linear mixed-effects model with binomial distribution was fitted for the nonword accuracy analyses with the same structure as the one in the nonword latency analyses. The results did not reveal any significant effects.

Simulation of Experiment 3

Experiment 3 was simulated with the same method as for Experiments 1 and 2. The model recognized correctly all the target stimuli as words. Mean predicted response times (cycles) are included in Table 5. The model predicted a 1 cycle facilitation effect in the no preprime condition, which was enhanced to 14 cycles in the identity preprime condition. Crucially, contrary to the observed results in the competitor preprime condition in Experiment 3, the model predicted a 1 cycle inhibitory effect in this condition, rather than a priming boost relative to the no preprime condition.

Discussion

The results in Experiment 3 showed a significant facilitation priming effect when the preprime was a high frequency neighbor and this effect was not only in the same direction as the identity preprime condition, but also numerically greater. The model's prediction did not match the empirical results as it included a priming boost relative to the conventional masked-priming paradigm only in the identity preprime condition. The evidence again ran in the opposite direction to that predicted by the idea that activation of lexical competitors eliminates or attenuates priming. These results suggested that the advantage of the sandwich priming paradigm over the conventional one could also be obtained by a preprime presentation of a similar to the target word, rather than the target itself and thus could not be attributed to the elimination of lexical competition effects.

General Discussion

The results from the present study showed that the masked form priming effect was increased not only after a brief preprime presentation of the target itself, but also after a presentation of a word orthographically related to the target. These results contradicted the predictions of the Spatial Coding Model (Davis, 2010), which predicted an increase of the priming effect only after a presentation of the target and an inhibitory influence of the presentation of a related word. In the interactive activation framework, the activation of such closely related candidates leads to inhibition of the target word and they are therefore considered to be target's competitors. Our study replicated the results of Lupker and Davis (2009) that the presentation of the target before the prime, as in the sandwich priming paradigm, produced priming effects that were not

present when the original masked priming was employed. Crucially, however, we extended their findings and demonstrated that this effect could also be achieved with a preprime presentation of a *competitor* word. As a presentation of a competitor should increase lexical competition, the results presented here thus contradict Lupker and Davis's interpretation that the sandwich priming procedure enhances priming by attenuating lexical competition processes. More specifically, the present results provided evidence that the brief presentation of the target as a preprime was not linked to mechanisms of suppression of targets' competitors. These findings suggested that the sandwich priming methodology could not be considered as a method overcoming the limitations of the conventional masked priming paradigm *by eliminating lexical competition effects*.

In the present study, we addressed the question of why the primes that failed to produce facilitation effects with the conventional masked priming paradigm did so with the sandwich priming. As we considered the evidence, provided by Lupker and Davis (2009) to be inconclusive for determining the nature of the sandwich priming effects, we tested their claim that a preprime presentation affected lexical competition processes. We followed the interactive activation and competition framework and aimed to provide more evidence by keeping lexical competition present. What is more, we aimed to enhance it. We did so by manipulating what and whether anything was presented before the prime. If the presentation of the target would activate the target's lexical representation and by doing that this advantage will lead to the elimination of lexical competition effects, then it should follow from that, that a presentation of a target's competitor before the prime would preactivate the target's competitor lexical representation, which would keep and even augment lexical competition effects. The claim of

Lupker and Davis was that moderately related primes could produce facilitation if lexical competition effects were filtered out. We explored whether moderately related primes could also produce priming with preprimes that clearly could not filter out lexical competition (and indeed should have the opposite effect).

In three different lexical decision experiments, we explored the priming effects of related primes by comparing them to an unrelated primes conditions. We did that comparison with three different procedures. We used the conventional masked priming procedure in which we presented only one brief prime, that was immediately followed by a target. We also used the procedure, suggested by Lupker and Davis (2009), in which we inserted the target's brief presentation before the prime. In the third procedure, we inserted a target's competitor before the presentation of the prime. We compared the obtained empirical results with the predictions of the Spatial Coding Model (Davis, 2010) that were specific to the used stimulus materials.

In our first experiment, we used the original Lupker and Davis (2009, Experiment 2) stimuli and chose the closest possible competitor for each target. The results showed that the priming effects in the competitor preprime conditions for the one and two-letter different primes was numerically larger, but not significantly different from the ones that were obtained when there was no preprime (conventional masked priming). These results did not accord with the prediction of the model of an attenuation of the priming effect in the competitor preprime condition, relative to the no preprime condition. Consistent with the model's predictions, however, and with the reported results by Lupker and Davis, a form priming boost was replicated in the identity preprime (original sandwich priming) condition. After such a target

preprime presentation, the priming effect in the one-letter different prime condition reached 59 ms. This effect was statistically different from the no preprime condition, but not from the competitor condition, suggesting a tendency of the competitor preprime towards producing a form priming boost. With an identity preprime, a significant facilitation effect was observed when the related primes were up to three-letter different from the target, thus differing from the competitor and the no preprime conditions.

In Experiment 2, we chose different targets that have orthographic neighbors and constructed stronger competitors for them. We chose high frequency words that differ by only one letter from the target. We expected that such a manipulation should afford strong inhibitory effects if indeed lexical competition was affecting priming results. In this experiment, all primes were one-letter different from the target as well as one-letter different from the competitor preprimes. All three preprime conditions produced significant facilitation. No trace of inhibition was introduced by the high-frequency target neighbors. These results stood in sharp contrast with the Spatial Coding Model's (Davis, 2010) prediction of a strong inhibitory priming effect in the competitor preprime condition. The model's prediction suggested that in an interactive-activation framework, the selected items were highly effective in triggering lexical competition processes in the context of the shared-neighbor primes and the lower frequency neighbor targets. Despite that, however, the priming effect in the competitor preprime condition in Experiment 2 remained in the opposite direction and did not differ significantly from the priming effect in the identity preprime condition.

With competitor preprime manipulation left aside, the results from the second experiment also showed that, although numerically 11 ms bigger, the 36 ms priming effect in the identity condition was also not statistically different from the one in the conventional masked priming condition. Unlike the sandwich priming boost in the one-letter different prime condition in Experiment 1, such a robust boost was not observed with the stimuli in Experiment 2. The priming effect was increased with 35 ms relative to the no preprime condition in Experiment 1 and with only 11 ms in Experiment 2. Apart from being one letter shorter, the targets in Experiment 2 differed from those in Experiment 1 by having a high frequency neighbor. In addition, related primes were constructed to be neighbors of both the target and the target's word neighbor. Previous studies have demonstrated that the size of the priming effect is reduced when target neighbor nonword primes and targets share a word neighbor (Van Heuven, Dijkstra, Grainger, & Schriefers, 2001). These findings have been interpreted in just this kind of the lexical competition framework: The explanation has been that when the prime is related to both the target and a competitor, this competitor becomes highly active and therefore influences the target negatively through the lateral inhibition mechanism in the related condition. If shared neighbors reduce the size of the priming effect even after the sandwich priming manipulation, then lexical competition, stated as a cause for decreased priming effects, is not eliminated by the preprime presentation of the target. The fact that the size of the sandwich priming boost was greater with targets that had no close competitors (Experiment 1) than with targets that had high frequency neighbors and were primed by shared-neighbor primes (Experiment 2) is consistent with the interpretation that sandwich priming does not address counteractive lexical competition effects. However, further investigation is needed

before drawing strong conclusions regarding the sandwich priming boost dependency on effects such as shared neighborhood, frequency and neighborhood size relationships between targets and competitors, and possibly target length.

Some evidence that the sandwich priming boost might be dependent on word length in a shared neighbor priming context comes from the obtained robust priming effect in the conventional masked priming condition in Experiment 2. This condition served as a baseline for evaluating the sandwich priming boost and was not significantly different from the identitypreprime condition. One apparent difference between the current study and a previous study, that had demonstrated that shared neighbor primes were not effective (Van Heuven, Dijkstra, Grainger, & Schriefers, 2001), was the length of the stimuli. The stimuli in Experiment 2 were six-letters long, while the items in Van Heuven et al. (2001) were four-letters long.

In Experiment 3, we sought to extend the findings with the three preprime manipulations and constructed the related prime condition by transposing all adjacent letters in the targets. Previous studies have shown that such primes do not differ from an unrelated condition when the original masked priming is used (Guerrera & Forster, 2008; Lupker & Davis, 2009). Our results were in accordance with those studies as we failed to establish a significant priming effect when there was no preprime. We also managed to replicate the significant difference between the related condition and the unrelated condition when the target was presented as a preprime that was found by Lupker and Davis (2009, Experiment 1). More important, though, we found that higher-frequency neighbors of the target enabled the same facilitation effect as the target words themselves (in fact, even numerically bigger) when they were presented as

preprimes. These results were again not in accordance with the Spatial Coding Model's (Davis, 2010) predictions.

These findings imply that the competitor preprimes did not inhibit the targets' recognition and could not be linked to lexical competition processes. On the contrary, the results from Experiments 2 and 3, in which the competitors highly resembled the targets and differed by only one letter from them, the cases in which they should produce most inhibition, they produced as much facilitation as the target preprimes did.

Like Lupker and Davis (2009), we found that the brief presentation of the target before the primes boosted masked form priming facilitation effects and even produced facilitatory priming in cases in which the traditional masked priming procedure could not. Our results were not however consistent with an interpretation that the obtained facilitatory orthographic priming effects were evidence that prime sandwiching was a manipulation that operated by reducing lexical competition effects. Considering the evidence presented here, one should not view a dual-prime paradigm, such as the sandwich priming paradigm, as a superior to the conventional masked-priming paradigm by virtue of reduction of competition. Such an interpretation is ruled out by our demonstration that the orthographic effects were not reversed and followed the same sandwich pattern when orthographic neighbors of the targets were presented as a preprime.

It appeared from the data presented here that the priming effect was boosted when both the preprimes and primes reached a high degree of similarity with the targets. In Experiment 1, when the competitor preprimes were more often more than one-letter different from the target,

the facilitation in the competitor preprime condition was evident only when the related primes were no more than two-letters different. Thus, the results in this preprime condition matched those in the no preprime condition. In Experiment 3, however, when the competitor preprimes differed by only one-letter from the target, the priming effect produced by transposed-all letter primes reached significance and was highly boosted by the presence of a preprime, regardless of whether the preprime was the competitor word or the target. We could thus infer that the orthographic priming effect produced in a sandwich priming paradigm was not a function of the similarity between the prime and the target, with lexical competition being filtered out, but rather of the joint similarity of the two primes with the target.

Such an interpretation is consistent with evidence provided by Forster (2009, 2013) that masked form primes did not produce significant priming effects when they were followed by another unrelated prime, rather than directly by the target. In his studies, Forster used a procedure that resembled the sandwich priming paradigm as it also included an additional processing event which was inserted in the conventional mask-prime-target sequence. As he explored the limits of obtaining a priming effect, his study contained different manipulations than those in the present study. Such differences include: order of presentation of the two primes, prime visibility (masked, unmasked) and prime type levels. An additional unrelated preprime served as a control for establishing the effect of an identity preprime and a one-letter different nonword form prime. When both primes were masked (both presented for 50 ms), an identity preprime produced a significant facilitation effect relative to the control when followed by an unrelated prime, but form prime did not. Forster concluded that identity priming operated on two levels: meaning and form, with only the processes taking place on the level of meaning being

unsusceptible to the effects of the dissimilar in form unrelated “intervenor”. These results, and the interactive nature of the sandwich priming boost observed in the present study, suggest that a masked orthographic priming effect requires a degree of consistency in the information provided by subsequent brief perceptual events.

A possible explanation of these observations could be that the presentation of the preprime in the present study enhanced the form priming effect by providing additional perceptual evidence that was consistent with the characteristics of the target. The priming effect is a function of the total amount of information consistent with the target that could be processed in such conditions from both the prime and preprime. It follows from the preprime and prime interaction that the accumulated evidence towards the target from the preprime alone is insufficient when there are two sequential priming visual events and an additional supporting evidence from the prime is needed to produce the facilitation effect. When the prime is related to the target (and the preprime), the total amount of inconsistent information is much less (in terms of wrong letter identities, and letter positions or both) and possibly the probability that it is detected is much lower in comparison to the unrelated prime condition. Thus, the difference between the related and unrelated prime conditions becomes significant. Interpretations of priming effects in terms of accumulating perceptual evidence from successive perceptual events are also made by proponents of the Bayesian Reader framework (Norris & Kinoshita, 2008).

Another interpretation of the results, and particularly the consistent sandwich priming boost with moderately related primes, could be described in the framework of the interactive-activation model (McClelland & Rumelhart, 1981) with mechanisms different from lexical competition. As

the name suggests, this account models the process of word recognition by the means of accumulation of activation of individual lexical units (word nodes), and higher levels of activation are associated with recognition. Facilitatory priming is therefore observed when the target word's node is more active at related prime offset than at control prime offset.

A word node's activation starts from a resting level, a negative number that is specific for each word node and is a function of the word's frequency, but is typically higher than the minimum (floor) activation associated with all nodes. When an input is presented that is sufficiently consistent with the node, the node's activity increases, while with a net inconsistent input the activity decreases. Therefore, the presentation of an unrelated prime will decrease the target's activation below its resting level, eventually pushing it towards the floor.

A prime, insufficiently consistent with the target, such as a transposed-all prime, could produce a similar effect. Although more slowly than with an unrelated prime presentation, the target's activation will also decrease due to a transposed-all prime and could reach the floor level by the time of the prime's offset. In this scenario, at the time of the target's onset, the activation of the target node will be at the same starting point, the floor level, in both the unrelated prime and the related transposed-all prime conditions. Therefore, in both conditions, the target node will need the same amount of time to raise its activity to the recognition threshold. Since there will be no difference between the two priming conditions, a priming effect, measured by that difference, would not be observed.

In sandwich priming scenarios, the first event is the preprime that is consistent with the target, rather than the prime that is not. Therefore, the target's activation will first increase above the

resting level, rather than decrease to the floor level (as in the no preprime condition). This increase could be achieved with both a target preprime and a one-letter-different from the target preprime (i.e., the competitor preprime condition). When the prime is presented as a second event, the level of the target's activation is sufficiently high to remain above the floor level until the offset of the inconsistent prime, at least in the transposed-all prime condition. In this condition, the activity decreases at a slower rate than the control due to this related prime's moderate similarity to the target. As the activity of the target will not drop to the floor level, or at least not in both priming conditions, it will be different for the two conditions at the time of the target's onset. The crucial difference between the conventional priming and the sandwich priming, therefore, is that a floor effect is observed in the former, while in the latter it is not. In conventional priming, at the time of the target's onset, the activation of the target node is at the same (floor) level in both priming conditions, while in sandwich priming, it is higher in the related transposed-all prime condition than in the unrelated one, allowing for a priming effect to occur.

An interpretation as the one in the interactive activation framework, however, considers all features of the stimuli and assumes that all information is processed in both the conventional masked priming and the sandwich masked priming conditions. Due to the additional visual event and the further processing time, however, the mechanisms involved might differ between the two masked priming paradigms and a straight comparison between the orthographic priming effects produced by both might not be absolutely informative, until more evidence is gathered about the perceptual processes that take place when two primes are briefly displayed. Interesting outstanding questions include the extent to which the preprime information is

processed, and in particular, when such information is inconsistent with the other two visual events (prime and target). Such information was, for example, the inconsistent one different letter in the competitor preprime in Experiment 3. Although the sandwich priming paradigm may not be superior to the original masked priming paradigm for the reasons stated by Lupker and Davis (2009), it may nevertheless be informative in the exploration of bottom up processes, early processing stages in visual recognition and capacity limitations of the processing system. A similar technique has already been employed for investigation of capacity limitations in several studies (Forster, 2009, 2013). A task that could be used as an alternative to the conventional masked-primed lexical decision for measuring orthographic similarity is the same-different task, which has been proposed as less susceptible to lexical effects and more sensitive for detecting small differences in priming effects (e.g. Kinoshita & Norris, 2009; Norris, Kinoshita, & van Casteren, 2010).

In conclusion, the present study provided evidence that the enhancement of the form priming effect produced in the sandwich priming paradigm in comparison to the conventional masked priming paradigm could not be attributed to the elimination of lexical competition processes. Rather, the results from the present study suggest that this effect have a different locus, such as bottom-up processes that operate on a prelexical level. The results from the present study thus not only question the mechanisms underlying the sandwich priming procedure, but they also provide more information about the nature and the boundaries of orthographic processing.

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Table 1

Mean Response Times (ms) and Error Rates (%) by Condition for Word Trials in Experiment 1

Preprime	Prime					
	(Different letters)					
	1	2	3	4	5	7
Identity	536 (3)	554 (1)	561 (3)	593 (4)	593 (6)	595 (6)
Competitor	547 (3)	567 (3)	582 (4)	592 (5)	592 (5)	589 (5)
None	555 (3)	562 (2)	565 (2)	577 (3)	583 (4)	579 (2)

Table 2

Mean Response Times (ms) and Error Rates (%) by Condition for Nonword Trials in Experiment 1

Preprime	Prime (Different letters)					
	1	2	3	4	5	7
Identity	642 (2)	637 (6)	642 (6)	648 (4)	630 (2)	644 (7)
Competitor	652 (6)	648 (4)	650 (5)	638 (5)	648 (5)	653 (3)
None	644 (3)	659 (7)	662 (5)	652 (5)	651 (6)	661 (2)

Table 3

Mean Response Times (ms) and Error Rates (%) by Condition for Word Trials in Experiment 2 and Response Times (cycles) by Condition in Simulation of Experiment 2

Prime	Preprime					
	Identity		Competitor		None	
	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation
One-letter different	623 (9)	76	634 (10)	157	631 (7)	111
Unrelated	659 (14)	113	667 (13)	115	656 (10)	114
Priming	36 (5)	37	33 (3)	-42	25 (3)	3

Table 4

Mean Response Times (ms) and Error Rates (%) by Condition for Nonword Trials in Experiment 2

Prime	Preprime		
	Identity	Competitor	None
One-letter different	696 (10)	701 (10)	707(8)
Unrelated	701 (8)	708 (9)	718 (9)
Priming	5 (-2)	7 (-1)	11(1)

Table 5

Mean Response Times (ms) and Error Rates (%) by Condition for Word Trials in Experiment 3 and Response Times (cycles) by Condition in Simulation of Experiment 3

Prime	Preprime					
	Identity		Competitor		None	
	Experiment	Simulation	Experiment	Simulation	Experiment	Simulation
Transposed-all	614 (10)	99	617 (9)	116	630 (9)	113
Unrelated	640 (14)	113	657 (13)	115	633 (12)	114
Priming	26 (4)	14	40 (4)	-1	3 (3)	1

Table 6

Mean Response Times (ms) and Error Rates (%) by Condition for Nonword Trials in Experiment 3

Prime	Preprime		
	Identity	Competitor	None
Transposed-all	698 (13)	701 (11)	701(10)
Unrelated	711 (12)	708 (11)	708 (11)
Priming	13 (-1)	7 (0)	7(1)

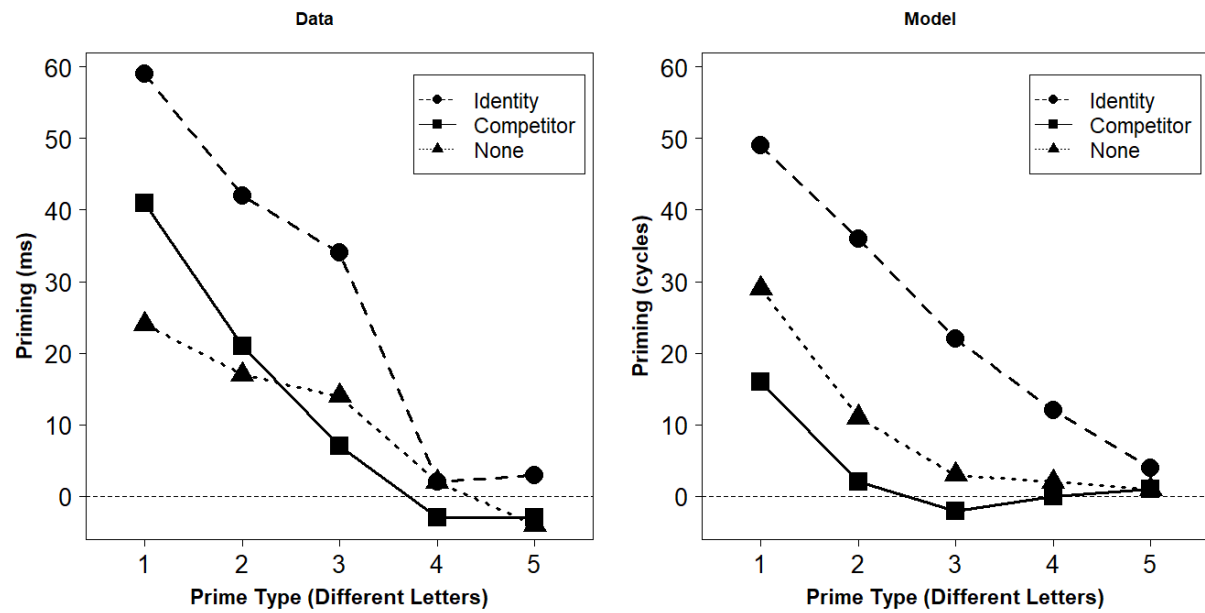


Figure 1. Priming effect (relative to the relevant all-letter-different control) in Experiment 1 (ms; left) and simulation of Experiment 1 (cycles; right), as a function of preprime type and prime type for word trials.

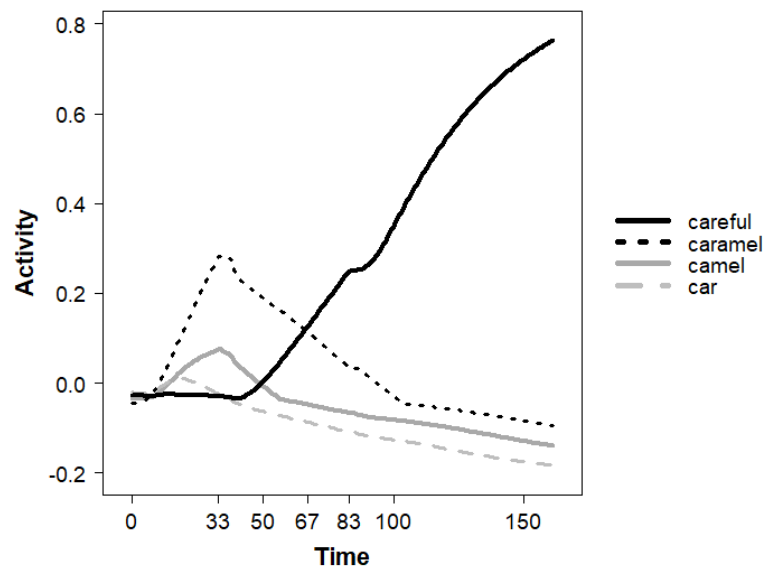


Figure 2. Words activity over time in the trial CAMEL-cvreful-CAREFUL from the simulation of Experiment 1.

Appendix A

Stimuli in Experiment 1

1-LD	2-LD	3-LD	4-LD	5-LD	7-LD	Target	Competitor
Word Trials							
axticle	axbicle	axbycle	axbvkle	axbvwe	nxbvwhm	ARTICLE	ARTISTE
csbinet	cslinet	cslnet	cslwvet	cslwvxt	rlwvxk	CABINET	CABARET
cvreful	cvmeiful	cvmsful	cvmsdul	cvmsdxl	wvmsdxk	CAREFUL	CAREMEL
czntral	czwtral	czwkral	czwkmal	czwkmsl	vzwkmsb	CENTRAL	CONTROL
cdapter	cdnpter	cdnqter	cdnqfer	cdnqfmr	wdnqfmz	CHAPTER	CHARTER
cbimate	cbwmate	cbwvate	cbwvste	cbwvsfe	nbwvsfn	CLIMATE	COINAGE
cvstume	cvxtume	cvxkume	cvxkme	cvxknze	wvxknzw	COSTUME	CONSUME
cvunter	cvxnter	cvxmter	cvxmker	cvxmkr	svxmks	COUNTER	CLUSTER
cnurage	cnwrage	cnwvage	cnwvmge	cnwvmqe	xnwvmqs	COURAGE	COINAGE
dsflight	dsflight	dsfxght	dsfxyht	dsfxybt	ksfxybk	DELIGHT	DEFIANT
dvstroy	dvctroy	dvckroy	dvckmoy	dvckmxy	fvckmxx	DESTROY	DESTINY
dmsplay	dmvplay	dmvglay	dmvgfay	dmvgfxy	hmvgfxj	DISPLAY	DISOBEY
fzctory	fzwtory	fzwdory	fzwdry	fzwdny	lzwdnj	FACTORY	FANTASY
fwculty	fwxulty	fwxsly	fwxshty	fwxshky	bwxsxhp	FACULTY	FALSITY
fmshion	fmvhion	fmvkion	fmvkcon	fmvkcxn	bmvkcxw	FASHION	FACTION
fwreign	fwzeign	fwzvign	fwzvmgn	fwzvmqn	dwzvmqc	FOREIGN	FOREMAN
fxrgive	fxsgive	fxspive	fxspmve	fxspmce	txspmcw	FORGIVE	FORGAVE
fmrula	fmrula	fmrwula	fmrwzla	fmrwzda	knwzds	FORMULA	FERRULE
fsrtune	fsmtune	fsmdune	fsmdcne	fsmdcwe	hsmdcwv	FORTUNE	FORGONE
fxneral	fxveral	fxvzral	fxvzsar	fxvzscl	kxvzsct	FUNERAL	FEDERAL
hzliday	hztiday	hztrday	hztrkay	hztrkny	bztrknp	HOLIDAY	HALFWAY
hzstile	hzntile	hznkile	hznkvle	hznkvbe	dznkvbw	HOSTILE	HOSTAGE
hvsband	hvxband	hvxkand	hvxkwnd	hvxkwmd	lvxkwml	HUSBAND	HOLLAND
icprove	icjrove	icjwove	icjwxve	icjwxze	scjwxzs	IMPROVE	IMPLORE
imclude	imzlude	imztude	imztsde	imztshe	wmztshw	INCLUDE	INCLINE
jvurney	jvxrney	jvxzney	jvxzmey	jvxzmsy	pvxzmsg	JOURNEY	JOINERY
jnstice	jnrlice	jnrlice	jnrldce	jnrldxe	gnrdvxw	JUSTICE	JASMINE
kvngdom	kvrgdom	kvrrpdom	kvrrphom	kvrrphxm	tvrrphxw	KINGDOM	GINGHAM
krtchen	krdchen	krdxhen	krdxlen	krdxln	frdxlsw	KITCHEN	KINSMEN
mvchine	mvshine	mvsdine	mvsdxne	mvsdxre	wvsdxrw	MACHINE	MACHETE
mwdical	mwtical	mwtvcal	mwtvxal	mwtvxnl	rwvtvxf	MEDICAL	MAGICAL
mxsical	mxvical	mxvncal	mxvnzal	mxvnzwl	rxvnzwl	MUSICAL	MARITAL
nxtwork	nxxwork	nxxzork	nxxzsrk	nxxzsvk	mxhzsvf	NETWORK	NEWBORN
pvymnt	pvqment	pvqrnt	pvqrwnt	pvqrwzt	gvqrwzf	PAYMENT	PATIENT
pvcture	pvnture	pvnkure	pvnkure	pvnkure	qvknwzs	PICTURE	PASTURE
phastic	phwstic	phwntic	phwndic	phwndvc	yhwndvr	PLASTIC	PHALLIC
pxverty	pxwerty	pxwzrty	pxwznty	pxwznhy	qxwznhy	POVERTY	PUBERTY

pwoduce	pxwduce	pwxlucde	pwxlsce	pwxlsve	jwxlsvn	PRODUCE	PROCURE
pxoduct	pxvduct	pxvkuct	pxvkwt	pxvkwtz	qxvkwzl	PRODUCT	PREDICT
pvoject	pvnject	pvnqect	pvnqsc	pvnqsm	gvnqsmf	PROJECT	PROTECT
pxomise	pxwmise	pxwvise	pxwvcse	pxwvcze	jxwvczn	PROMISE	PREMISE
pvotein	pvmtein	pvmfein	pvmfsin	pvmfszn	qvmfszc	PROTEIN	PROTEAN
psovide	psnvide	psnmide	psnmzde	psnmzte	ysnmztx	PROVIDE	PRESIDE
qvality	qvslity	qvsfity	qvsfmy	qvsfmky	gvsfmkj	QUALITY	QUALIFY
rcspond	rcwpond	rcwjond	rcwjznd	rcwjzxd	vcwjzxd	RESPOND	RESOUND
rxutine	rxwtine	rxwdine	rxwdzne	rxwdzse	vxwdzsm	ROUTINE	RAGTIME
scrvant	scmvant	scmzant	scmzwnt	scmzwct	xcmzwcd	SERVANT	SERPENT
sxdier	sxtier	sxtkier	sxtkver	sxtkvwr	nxtkvwc	SOLDIER	SILLIER
sdomach	sdzmach	sdzrach	sdzrwch	sdzrwnh	vdzrwnk	STOMACH	SPINACH
Shorage	shwrage	shwcage	shwcvge	shwcvye	xhwcvyn	STORAGE	SALVAGE
swrface	swmface	swmhace	swmhxce	swmhxeze	nwmhxzn	SURFACE	SUFFICE
tciumph	tcvumph	tcvsmph	tcvswph	tcvswyh	bcvswyl	TRIUMPH	TALLISH
tzouble	tzvuble	tzvxble	tzvxfle	tzvxfhe	dzvxfhs	TROUBLE	TREMBLE
tjpicl	tjqicl	tjqvcal	tjqvral	tjqvrsl	hjqvrsl	TYPICAL	TOPICAL
uviform	uvwform	uvwhorm	uvwhxrm	uvwhxsm	cvwhxsz	UNIFORM	UNICORN
ujright	ujcight	ujcvght	ujcvyht	ujcvyft	xjcvyfk	UPRIGHT	UPTIGHT
vsriety	vsziety	vszmety	vszmwty	vszmwky	nszmwkg	VARIETY	VARSITY
vzrsion	vzcsion	vzcmion	vzcmwon	vzcmwzn	xzcmwzx	VERSION	VENISON
vwctory	vwstory	vwsitory	vwsixry	vwsixny	mwsixnj	VICTORY	VICEROY
wvrship	wvnship	wvnchip	wvnclip	wvnclzp	xvnclzq	WORSHIP	WARSHIP
Nonword Trials							
twobide	twmbide	twmhide	twmhzde	twmhzfe	lwmhzhfx	TROBIDE	TRYBIDE
vsdilar	vshilar	vshzlar	vshztar	vshztmr	nshztmx	VIDILAR	VIDIJAR
lstchen	lsdchen	lsdwhen	lsdwfen	lsdwfxn	ksdwfxr	LETCHEN	LETXHEN
dzpimal	dzyimal	dzynmal	dzynxal	dzynxsl	hzyynxsf	DAPIMAL	DJPIMAL
svralge	svnalge	svnzlge	svnzhe	svnzhe	wvnzhjm	SCRALGE	SCRAKGE
dwrplex	dwmplex	dwmjlex	dwmjbex	dwmjbcx	fwmjbcn	DORPLEX	DOKPLEX
dsfture	dskture	dskbure	dskbwre	dskbwne	hskbwne	DIFTURE	DIFTULE
wzrbace	wzvbase	wzvbase	wzvbase	wzvbase	xzvbase	WURBACE	WURBAME
onelage	onclage	oncfage	oncfwge	oncfwje	mncfwjz	OVELAGE	OVELAGC
psurcil	pszrcil	pszmil	pszmwil	pszmwvl	gszmwvd	POURCIL	POURGIL
bslerce	bsderce	bsdwrce	bsdwxce	bsdwxne	hsdwxnv	BILERCE	BILEWCE
sbrvent	sbrvent	sbrxent	sbrxznt	sbrxzmt	wbrxzmk	SLUVENT	SLUKENT
fwrbose	fwmbose	fwmhose	fwmhcse	fwmhcve	lwmhcvx	FURBOSE	FUQBOSE
bvferce	bvkerce	bvkxrce	bvkxzce	bvkxzne	dvkxzns	BEFERCE	BEFEWCE
kslefit	ksbefit	ksbxfit	ksbxhit	ksbxhrt	dsbxhrd	KELEFIT	KELEXIT
asprain	asyrain	asyzain	asyzwin	asyzwmn	csyzwmc	AXPRAIN	AXPCAIN
txpular	txjular	txjmlar	txjmhar	txjmhr	fxjmhr	TEPULAR	TQPULAR
sboromy	sboxromy	sboxvomy	sboxvnm	sboxvnc	wboxvnc	STOROMY	STOPOMY
dxanity	dxvnity	dxvsity	dxvswty	dxvswy	fxvswy	DEANITY	DEANFTY

frlance	frtance	frtvnce	frtvsce	frtvswe	drtvswx	FOLANCE	FOLGNCE
bxdfital	bxdfital	bxdfstal	bxdfshal	bxdfshzl	kxfshzk	BEDITAL	BEDIFAL
swnfact	swzfact	swzhact	swzhmct	swzhmvt	xwzhmvt	SONFACT	SJNFACT
mzverop	mzwerop	mzwsrop	mzwscop	mzwscxp	nzwscxy	MEVEROP	MEVEROK
dsrfelt	dszfelt	dszkelt	dszkclt	dszkcbt	hszkcbh	DERFELT	DERFEVT
avagour	avcgour	avcqour	avcqzur	avcqzxr	svcqzxw	AMAGOUR	ABAGOUR
bslefom	bshefom	bshvfom	bshvtom	bshvtwm	dshvtwc	BOLEFOM	DOLEFOM
cmfpete	cmfpete	cmfqete	cmfqste	cmfqshe	wmfqshx	CALPETE	CAHPETE
cfonity	cfmity	cfwity	cfwsty	cfwsky	xfrwskp	CHONITY	CVONITY
cvdselt	cvkselt	cvkzelt	cvkzrlt	cvkzrht	wvkzrhb	CODSELT	CWDSELT
etkeror	etderor	etdwror	etdwxor	etdwxml	stdwxmv	ELKEROR	EFKEROR
fmlpion	fmdpion	fmdqion	fmdqvion	fmdqvrn	hmdqvrw	FILPION	FILPIHN
hvlbony	hvfbonny	hvftony	hvftrny	hvftrzy	dvftrzy	HALBONY	HALBVNY
iwbelse	iwtelse	iwtzlse	iwtzdse	iwtzdxs	cwtzdxn	IMBELSE	IMBETSE
lmdance	lmfance	lmfwnce	lmfwrcs	lmfwrxs	hmfwrxs	LIDANCE	LTDANCE
mvfster	mvdster	mvdcter	mvdcker	mvdckzr	wvdckzn	MAFSTER	MLFSTER
nrxvral	nxzvrsl	nxzmral	nxzmsal	nxzmssl	wxzmscf	NERVRAL	NERVRQL
pxdefic	pxkefic	pxkwfic	pxkwlic	pxkwlrz	jxkwlrz	PADEFIC	PYDEFIC
pzvulty	pzculty	pzcxlty	pzcxbty	pzcxbfy	jzcxbfy	PEVULTY	PEVUDTY
pselacy	pswlacy	pswfacy	pswfczy	pswfczy	gswfczy	PRELACY	PFELACY
rcdival	rchival	rchwval	rchwnal	rchwnsl	xchwnsb	REDIVAL	REDIVWL
syorvet	sywrvet	sywzvet	sywzcet	sywzcet	xywzcet	SPORVET	SPORVGT
snvitor	sncitor	sncxtor	sncxdor	sncxdmr	wncxdmr	SEVITOR	SEVWTOR
tcamial	tcwmial	tcwsial	tcwszal	tcwszvl	kcwszvl	TRAMIAL	TRABIAL
wkasber	wkmsber	wkmbver	wkmbver	wkmbvtr	ckmbvtr	WHASBER	WHASBQR
egilade	egmlade	egmfade	egmfwde	egmfwte	xgmfwte	EPILADE	EPIGADE
syueane	syweane	sywrane	sywrmne	sywrmve	xywrmvz	SQUEANE	SQBEANE
tnshure	tnxhure	tnxbure	tnxbmre	tnxbmce	fnxbmcw	TOSHURE	TOSDURE
oxlbard	oxkbard	oxkhard	oxkhwrz	oxkhwvd	nxkhwvt	OULBARD	OULBXRZ
tlagger	tlmgger	tlmqger	tlmqjer	tlmqjwr	klmqjwr	THAGGER	THASGER
srslven	srxlven	srxlven	srxlzen	srxlzen	mxlzen	SWALVEN	SWAQVEN
mnfbical	mnfbical	mnfbical	mnfbical	mnfbical	wnfbical	MABICAL	MABICFL
gvemmar	gvsmmar	gvswmar	gvswcar	gvswcar	qvswcar	GREMMAR	GNEMMAR
qxandel	qxcndel	qxcvdel	qxcvkel	qxcvkzl	yxcvkzb	QUANDEL	QUAFDEL
mwrforry	mwrforry	mwrforry	mwrforry	mwrforry	xwrforry	MERFORRY	MERFORD
ovatelj	ovatelj	ovatelj	ovatelj	ovatelj	mvatelj	ONATELJ	OGATELJ
cwngarm	cwxgarm	cwxparm	cwxpsrm	cwxpszm	vwxpszm	CONGARM	COQGARM
crndial	crvdial	crvhial	crvhial	crvhial	xrvhial	CONDIAL	CONDIXL
grbadic	grladic	grlvdic	grlvkic	grlvkwc	prlvkwn	GEBADIC	GEBADIW
cxnvent	cxsvnt	cxswnt	cxswznt	cxswzmt	rxswzmk	CANVENT	CGNVENT
dvflare	dvhlare	dvhtare	dvhtnre	dvhtnwe	kvhtnwc	DEFLARE	DMFLARE

(Appendixes continue)

Appendix B

Stimuli in Experiment 2

Related prime competitor	Unrelated prime competitor	Related prime identity	Unrelated prime identity	Related prime no	Unrelated prime no	Target	Competitor
Word Trials							
aqound	vfxwyi	apound	clqezw	azound	wlyvxe	ABOUND	AROUND
aczing	wrpqlj	acqing	xsmuob	acring	qjovwr	ACHING	ACTING
arjful	ponqdh	arwful	ipbowg	ariful	cjzkgw	ARTFUL	ARMFUL
lanish	woledz	danish	rkmedo	uanish	jpmowr	BANISH	VANISH
bfards	tyhzql	bgards	jzylmc	bhards	lkizwy	BEARDS	BOARDS
ieckon	gtyliv	deckon	sjdthy	weckon	tispaw	BECKON	RECKON
bkeach	kzdmgn	bveach	kiufos	bfeach	vjgmwq	BLEACH	BREACH
bridfe	uxcnw	bridae	cmqzyj	bridfe	asoxkv	BRIDLE	BRIDGE
aruise	zymhvx	aruise	xhzjlp	jruise	dojqvk	BRUISE	CRUISE
iandle	urzkgb	jandle	ptjvyk	qandle	ywtmzf	CANDLE	HANDLE
iasket	uoqdgp	zasket	vowlhr	xasket	duhrwx	CASKET	BASKET
chagts	iljzbv	chavts	mybfdl	chadts	efgqwj	CHANTS	CHARTS
chiues	lugqbk	chines	rpdfnk	chiwes	fodaxw	CHIVES	CHIMES
plawed	nrmsgj	blawed	yxzjq	slawed	yoikzq	CLAWED	FLAWED
cxowns	dhtmx	ceowns	fyxizm	ceowns	dfgixj	CLOWNS	CROWNS
coajed	rbfqlu	coaved	zujnwr	coaqed	fjgsnz	COAXED	COATED
qoward	unvipj	goward	gufsjy	eoward	sgqpuv	COWARD	TOWARD
xringe	bmtptju	bringe	lbxzov	bringe	aqjpmx	CRINGE	FRINGE
devths	lnibxr	dekths	fbjorv	devths	ybmfn	DEPTHS	DEATHS
ezotic	bjpgdyw	eyotic	lwjqup	eaotic	uqgwln	EROTIC	EXOTIC
flgshy	txujqz	flushy	rtogiv	flmshy	dtepbm	FLASHY	FLESHY
gvants	lukzef	gxants	bkjdox	gyants	mcojz	GIANTS	GRANTS
glopes	irnwtm	gloxes	pnwymq	glotes	xkcunj	GLOBES	GLOVES
grapts	ljdimz	grapks	xwcmfq	grapns	kwvufj	GRAPHS	GRAPES
vockey	qugrdl	nockey	lvnfud	qockey	pltgzm	JOCKEY	HOCKEY
eoints	gckzrb	koints	mfdyrk	loints	eqdhuy	JOINTS	POINTS
kemons	cuwzqp	gemon	rapbzx	uemon	pkxzvc	LEMONS	DEMONS
sizard	nktuoq	oizard	nfbejq	gizard	yfuobe	LIZARD	WIZARD
malure	zwfpil	mazure	gvzpkj	mabure	gqjcl	MANURE	MATURE
lighty	jpofdx	aighty	qjzxc	vighty	pkajbw	MIGHTY	EIGHTY
nivels	ugqimt	npvels	bzdyrg	nrvels	dqymir	NAVELS	NOVELS
noxice	ghdjak	noaice	fdaqhy	nowice	gpmalx	NOVICE	NOTICE
paiced	buyjfx	paiced	wcvhft	paiced	oxsfwh	PAIRED	PAINED
pbrish	jzyxbv	pmrish	junokv	pcrish	xjluoq	PERISH	PARISH
placsd	bsxjtu	plackd	ouyqth	placud	qmufyw	PLACID	PLACED
plazue	tszrfi	plamue	rcksby	platue	vtbywo	PLAQUE	PLAGUE

pzrtly	gzicuj	pkrtyl	wgnecu	pgrtly	cqhjuz	PORTLY	PARTLY
rounce	ydlzgw	gounce	xhwryv	dounce	khrgsi	POUNCE	BOUNCE
sreach	vmiodl	yreach	sfownv	vreach	lgjzwd	PREACH	BREACH
quotps	kgilrf	quotfs	dylfcr	quotrs	dliymr	QUOTAS	QUOTES
vesign	wzyout	qesign	lmtcaw	fesign	ywpzlo	RESIGN	DESIGN
sjmple	cdfgbh	swmple	krwdoq	scmple	hrxfjb	SAMPLE	SIMPLE
janity	mjpgdq	canity	mczwep	ganity	rojcup	SANITY	VANITY
sxrawl	zgnbhi	smrawl	megdiy	sjrawl	bgdmjk	SCRAWL	SPRAWL
shrinc	czdyvp	shriny	wfzayd	shrinq	pczavy	SHRINE	SHRINK
sgiver	jcfaqb	sniver	ywpqug	suiver	qzwbmd	SLIVER	SHIVER
spiwal	cyuvzw	spihal	edtmzq	spifal	zvwvyjh	SPINAL	SPIRAL
spaint	wyqgab	speint	bjzwac	spaint	huckda	SPLINT	SPRINT
squear	zpgjdb	squeab	yjvpgr	squeaw	nbrxgc	SQUEAL	SQUEAK
squikt	mhlzgz	squilt	czfew	squimt	jwmhva	SQUINT	SQUIRT
smarch	jidbxi	snarch	oyqbkx	sbarch	jwdzuo	STARCH	SEARCH
steafy	vzhoix	steahy	vpcgwI	steaoy	hofblg	STEAMY	STEADY
uneaid	jbtwmy	unwaid	kvzqrm	unoaid	wrjvol	UNSAID	UNPAID
urable	tdikyr	uyable	djzmpf	uvable	qyxjik	USABLE	UNABLE
gaults	edcwhj	iaults	kqocdg	paults	rdyiok	VAULTS	FAULTS
bortex	qfdpnu	fortex	izdhaw	lortex	akzfdp	VORTEX	CORTEX
wrevch	oxyqdi	wreqch	ujibfs	wreich	qaljyi	WRETCH	WRENCH
pouths	pxqcwk	rouths	ngvxbw	gouths	rwpbzl	YOUTHS	MOUTHS
savern	ihygpq	bavern	ubqfpl	savern	zlsjky	CAVERN	TAVERN
revtal	sjkmqp	reztal	ygqowz	rejtal	qpsivu	RECTAL	RENTAL
soream	qwoylv	soream	jhliup	sjream	zxudlh	SCREAM	STREAM
xorbid	thjzvn	jorbid	qskhcw	porbid	gpzvcx	FORBID	MORBID
merbal	ikqmou	werbal	ignfod	uerbal	ofwczg	HERBAL	VERBAL
aermit	sojbgd	fermit	vjgzxw	zermit	nfxoqa	HERMIT	PERMIT
vowled	ypafix	vowled	pcrjgq	cowled	mujvxx	HOWLED	BOWLED
qegion	sjzhpj	teqion	vcqshz	teqion	svzcbx	LEGION	REGION
suxked	tphjvz	sugked	prownv	suqked	bamqvz	SULKED	SUCKED
chails	bujwty	chaims	wvxoyy	chaibs	kvgtbd	CHAINS	CHAIRS
pistou	kuhdxj	pistou	xwjgch	pistox	zwqmju	PISTON	PISTOL
stafle	ydhcoi	stawle	hqgrfu	stajle	dwnmch	STAPLE	STABLE
trisle	dykhgo	triule	xhbvcn	trizle	kwhdab	TRIPLE	TRIFLE
raniom	qhwgex	rangom	lfiuxz	ranwom	tybqiz	RANSOM	RANDOM
deqour	gaxnlm	deiour	lxsnfq	dekour	yxcbpw	DETOUR	DEVOUR
gailor	egpwkj	failor	ebhyph	cailor	vuhekg	TAILOR	SAILOR
mildeu	uvabnt	mildeb	unyqkz	milden	scgjop	MILDEW	MILDER
outlar	ikrxvf	outlad	gepcsq	outlaf	rxcsnz	OUTLAW	OUTLAY
qreath	ouyxml	ireath	uldcog	kreath	jfvinx	WREATH	BREATH
convep	mldkpr	convek	jbadzg	convei	kfgald	CONVEX	CONVEY

Nonword Trials							
avouse	wjvfc	alouse	xikyqc	abouse	ctkwhy	ANOUSE	AROUSE
enuing	lqjrzw	enming	vpqslk	enting	tkkfy	ENCING	ENDING
aktral	gkjhwc	aftral	npzyqd	aitral	fjnwpo	ARTRAL	ASTRAL
canide	hdxjtw	caniye	ydlukg	caniqe	vmguly	CANISE	CANINE
pealms	tqnzgu	uealms	fivwyg	uealms	cpxqfh	BEALMS	REALMS
cuckoi	bpxyam	cuckor	vfthag	cuckoi	hprxtw	CUCKON	CUCKOO
bzeaks	umniyo	bqeaks	nmjztq	boeaks	ygtwqo	BLEAKS	BREAKS
fwible	dzcasq	fcible	jwchtu	fvible	swhtnj	FLIBLE	FOIBLE
sluice	mnwopd	sluioe	pthmok	sluiwe	bqpgvf	SLUISE	SLUICE
garble	yhsun	varble	fxkdyj	harble	wyogdj	CARBLE	MARBLE
caghet	fuxwgs	caohet	dorfbn	cadhet	wrxqno	CAMHET	CACHET
jhatch	xnlrgs	ehatch	ypzwib	ghatch	gmsuvn	CHATCH	THATCH
chrsts	opkyrl	chosts	qjowud	chfsts	nuwvrj	CHISTS	CHESTS
cldtch	vnezxd	clvtch	ibmqjr	clvtch	jxgsvr	CLATCH	CLUTCH
clohds	wyjveq	clovds	vbnejw	clonds	yhtfik	CLOUDS	CLOUDS
koathe	zyvrgp	voathe	idxwjg	goathe	ufyzvj	COATHE	LOATHE
cqrte	kzysiv	cmrate	gbsdzm	cmrate	qwgidy	CORATE	CURATE
zrithe	dobfpv	drithe	jgyxob	brithe	ksjmpl	CRITHE	WRITHE
mength	akxfr	pength	bmayox	iength	iuobrw	DENGTH	LENGTH
etxnic	xplgra	etwnic	xsofga	etjnic	davqsr	ETUNIC	ETHNIC
suandy	oefmtc	sfandy	bzxljt	slandy	tjzoev	SPANDY	SHANDY
wivlds	kgymox	wiqlds	jrcqmn	wiglds	ogkmbh	WIALDS	WIELDS
zrobes	nyxdlg	zrobes	uyikgf	xrobes	nzajqk	WROBES	PROBES
gracns	wtpeom	graons	lvxpbn	grakns	yzjft	GRAUNS	GRAINS
fickey	oaslud	oickey	arwobs	jickey	jwgsuq	VICKEY	MICKEY
wonths	qvrxd	qonths	xdqicp	donths	xyikcl	JONTHS	MONTHS
iepts	fhcugq	qepots	hyawkg	cepts	bxgauh	LEPOTS	DEPOTS
cazard	ymsgln	iazard	tyuomk	nazard	mbiygj	FAZARD	HAZARD
manogs	ldbfzh	manofs	dcqhwh	manohs	huyvvg	MANOPS	MANORS
corthy	jslqbc	corthy	ueqpln	vorthy	zdbgqn	MORTHY	WORTHY
wanals	ygrkd	xanals	oqpbuw	zanals	vudqkz	NANALS	CANALS
xevice	ykmfzd	kevice	qtsfjp	aevice	xztbpc	NEVICE	REVICE
garmth	sfndk	oarmth	blnxou	uarmth	jukqfb	PARMTH	WARMTH
mrdis	gjtbru	madish	ckjzgl	mrdis	nxzljy	MEDISH	MODISH
spaynd	cwjfbz	spayld	unltfh	spayfd	bfwqxz	SPAYID	SPAYED
plaoce	zujgw	plaoce	ntdjfq	playce	mwzsnx	PLARCE	PLAICE
mosqly	xcqpfz	mosdly	fbqjwn	mosuly	awuphb	MOSKLY	MOSTLY
fourts	enbdmj	jourts	eanqwh	jourts	nkvig	POURTS	COURTS
erouch	evnwvg	irouch	siezya	wrouch	nqfmzt	PROUCH	CROUCH
ihotos	mwfxc	xhotos	xqfiwg	ihotos	vzfbk	THOTOS	PHOTOS
resake	mqzudx	resane	ytoqgu	resave	vzfdk	RESAPE	RESALE
rathle	fogibk	ratkle	fydhkw	ratule	dbsucv	RATPLE	RATTLE

muziny	awcrvp	mujiny	cqvxyz	muxiny	jvapzx	MUNINY	MUTINY
scrals	fydtvo	scrahs	qugxey	scrags	dfihtm	SCRACS	SCRAPS
shriyt	olunaj	shriot	qegbux	shribt	cvagbx	SHRIST	SHRIFT
suider	ljhxyb	snider	aqgvck	syider	xblnzt	SWIDER	SPIDER
spilit	juovqf	spidit	wexqfm	spibit	qhxyzwv	SPINIT	SPIRIT
splids	waqexk	spliks	qehcwg	spliws	dmrjxy	SPLIBS	SPLITS
squejl	whvtdk	squejl	yxcpbn	squehl	jxmgrc	SQUEEL	SQUEAL
squice	zancyx	squihe	xtwdyp	squiwe	flwghb	SQUIVE	SQUIRE
staroe	uiqkwn	starpe	dfwyuo	starxe	oyncfx	STARGE	STARVE
steexy	djvxru	steefy	orwvxh	steewy	fmrwdh	STEKEY	STEELY
unhipe	jcdmqh	unzipe	qjgwal	unmipe	xywkav	UNSIPE	UNRIPE
oyacle	npdhju	okacle	zkmqnd	oxacle	hybgms	OTACLE	ORACLE
iawked	tsprox	xawked	bsjqmo	lawked	zxurqp	VAWKED	HAWKED
sertex	yqnpvc	hertex	npdcsl	kertex	cndfgv	JERTEX	AERTEX
irends	auhyjl	hrends	glqihx	jrends	afhmju	WRENDS	TRENDS
lnched	pjluxt	vnched	mfatwx	gnched	rjzngo	YNCHED	INCHED
cadegs	gpjlqi	cadeus	qglwnf	cadeis	zjugkw	CADEMS	CADETS
recuil	qbatpn	recuil	nvfgbm	recmil	zjtgnq	RECSIL	RECOIL
threao	bqxylg	threal	ojxzfz	threan	wkixuj	THREAM	THREAD
curgid	hkybnl	yurgid	pzneyc	purgid	pweyjj	FURGID	TURGID
yungal	mcpvrb	iungal	trswec	pungal	ejbdkr	HUNGAL	FUNGAL
dubmit	ajpczy	aubmit	vnxqcg	kubmit	flnqcd	HUBMIT	SUBMIT
forpse	mugfnz	qorpse	bljnkz	worpse	fkydqu	HORPSE	CORPSE
iemean	rycvou	uemean	fiktgu	oemean	vugjbr	LEMEAN	DEMEAN
suroed	yzmnba	surjed	lnbkvv	surxed	mwbvtt	SURPED	SURGED
chaqps	ijuztl	chazps	igrbdv	chaxps	ovnjil	CHAWPS	CHAMPS
custod	wevrqx	custoa	zljxph	custoy	hazyjg	CUSTON	CUSTOM
czadle	kuwynj	cnadle	wpnbyo	cjadle	wusxjz	CHADLE	CRADLE
primlx	gskcwz	primlz	tsznco	primlj	zktcab	PRIMLE	PRIMLY
eannoy	jchves	wannoy	uwdgxs	dannoy	cqfjug	RANNOY	TANNOY
rwgour	yxcdfn	rsgour	pfcbbs	rlgour	daxjhp	REGOUR	RIGOUR
facjor	pbuwgm	facnor	gnzimh	facdor	nxqkwb	FACLOR	FACTOR
midgeb	zbnlvk	midgeo	zxpbnz	midgek	ybrxnz	MIDGEW	MIDGET
outkay	mhgbei	outjay	hfsiqv	outvay	cxezgr	OUTNAY	OUTLAY
soeath	cqfbil	sceath	wknoig	sbeath	ubdoqy	SMEATH	SHEATH
confed	savigy	confez	aipxvq	confev	sgauit	CONFEW	CONFER

(Appendixes continue)

Appendix C

Stimuli in Experiment 3

T-all prime	Unrelated prime competitor	Unrelated prime identity	Unrelated prime no	Target	Competitor
Word Trials					
bauodn	hqtpic	iwjety	ifymqg	ABOUND	AROUND
caihgn	xfyqju	yjxbls	wjefby	ACHING	ACTING
raftlu	vosdeg	xsjbed	oecikp	ARTFUL	ARMFUL
abinhs	depuqg	yeuotf	ckpxlf	BANISH	VANISH
ebrasd	mnxlcz	ytuelw	vicqpj	BEARDS	BOARDS
ebkcno	ltmivp	luxzqd	ytmazx	BECKON	RECKON
lbaehc	ktjmzn	ujvxyf	oizxwq	BLEACH	BREACH
rbdiel	kjfumw	fcupam	jtposq	BRIDLE	BRIDGE
rbiues	wfopdq	mznahq	xknhgz	BRUISE	CRUISE
acdnel	wvogqm	pyfvmi	ktsiqy	CANDLE	HANDLE
ackste	jgvyro	wivrqg	igxlhd	CASKET	BASKET
hcnast	xlzjpm	gjwvml	jbpjom	CHANTS	CHARTS
hcvisc	wakpuy	rpfkag	kabqxt	CHIVES	CHIMES
lcwade	kohnms	yzjpxh	bzvkmn	CLAWED	FLAWED
lcwosn	mhbjoy	ikqzeu	fphayd	CLOWNS	CROWNS
ocxade	knbsuf	qifuzy	rnfibh	COAXED	COATED
ocawdr	begivl	gsluxm	leufhn	COWARD	TOWARD
rcnieg	mkytwd	mwphqb	olyaph	CRINGE	FRINGE
edtpsh	ywfbjq	gqfrix	bnqyrf	DEPTHS	DEATHS
retoci	wvjmsg	wypsgu	nbfdlq	EROTIC	EXOTIC
lfsayh	nrkci	pvunmi	rbzxng	FLASHY	FLESHY
ignast	wcypmb	wdobzc	ckyuwo	GIANTS	GRANTS
lgbose	twufxj	jztdxr	kqrwxu	GLOBES	GLOVES
rgpash	zcxqdj	bmkvxj	ovkbed	GRAPHS	GRAPES
ojkcyo	mnpfqd	uxdfts	nsldtu	JOCKEY	HOCKEY
ojnist	qyebvx	yhxklz	mcehbr	JOINTS	POINTS
elomsn	rlybpz	zxcpgw	gvbypt	LEMONS	DEMONS
ilazdr	yboxne	buoxqc	jxobsm	LIZARD	WIZARD
amuner	bpvyli	qlcvxk	xdbqoi	MANURE	MATURE
imhgyt	pndxbq	arnxvp	flnwox	MIGHTY	EIGHTY
anevsl	xpzkdr	rtwkjd	fwigdq	NAVELS	NOVELS
onivcc	lxsmby	zhqgwu	sdukhg	NOVICE	NOTICE
apride	ocglsb	cztklg	mkqovl	PAIRED	PAINED
epirhs	fbtjwl	wbmzut	dutwlv	PERISH	PARISH
lpcadi	rkhnvs	onwxzf	vfuxog	PLACID	PLACED
lpqaeu	yotmwn	xnwhyk	iowmdf	PLAQUE	PLAGUE

optryl	cishkf	ukbhzi	mwnskg	PORTLY	PARTLY
opnuec	qxmks	rsgiq	jktqif	POUNCE	BOUNCE
rpaehc	dzlyow	iwugdv	dnsczj	PREACH	BREACH
uqtosa	rvnyxp	jnfhvb	wzrpby	QUOTAS	QUOTES
erisng	pbqzlw	akuxzh	cvmbf	RESIGN	DESIGN
aspmel	fhrjkb	hoqgdx	ugvyqj	SAMPLE	SIMPLE
asinyt	mzwblu	mkdfjp	kgmrcz	SANITY	VANITY
csarlw	eyzmt	kfgdtq	mbeqxf	SCRAWL	SPRAWL
hsiren	lwqgay	fouqlt	adoxcp	SHRINE	SHRINK
lsvire	poatcn	ypgctd	zdactx	SLIVER	SHIVER
psnila	jtwyuc	hmqcou	uehdwb	SPINAL	SPIRAL
psiltn	wbvjkq	aehxkb	xfckmg	SPLINT	SPRINT
qseula	jrptfn	vcjbdm	cxnrgz	SQUEAL	SQUEAK
qsiutn	zmjxwb	kpovwy	clgpky	SQUINT	SQUIRT
tsrahc	godzvu	ldybfu	jovnpq	STARCH	SEARCH
tsaeym	upkzvo	kxwpuq	ohlfnu	STEAMY	STEADY
nuasdi	owhqtb	gebtcx	mltroe	UNSAID	UNPAID
subael	ivymqx	fxyhki	wrtkjh	USABLE	UNABLE
avlust	qnbjrg	noikre	nohidp	VAULTS	FAULTS
ovtrxe	zmhuji	gakibf	hwjgik	VORTEX	CORTEX
rwtehc	vfzxjp	iolgfv	klvudy	WRETCH	WRENCH
oytush	fpenzq	qgbfkv	lrgvpx	YOUTHS	MOUTHS
acevnr	hqswdg	qpmjgb	xhmwyg	CAVERN	TAVERN
ertcla	oijbzx	muojbz	qifxmb	RECTAL	RENTAL
cserma	klbuop	qbwfdh	kfdboz	SCREAM	STREAM
ofbrdi	jngzwa	exqwyv	gqwkjt	FORBID	MORBID
ehbrla	qdyngz	cqztsx	fzxsjd	HERBAL	VERBAL
ehmrtd	sawxgz	kcnzjq	bdwokq	HERMIT	PERMIT
ohlwde	nycfpg	rxaiyu	mnargk	HOWLED	BOWLED
eligno	tsacdx	zbtjma	tyxjaz	LEGION	REGION
usklde	rbmaho	wprymf	vxbyrp	SULKED	SUCKED
hciasn	zmvbld	qltxwd	mqgfzp	CHAINS	CHAIRS
iptsno	ufzbek	dweqgx	vdukgx	PISTON	PISTOL
tspael	qxvjgi	gyzdir	wdfjkc	STAPLE	STABLE
rtpiel	jgzahm	jsvknm	hamsoz	TRIPLE	TRIFLE
arsnmo	guctzh	exiqyc	qvlgpw	RANSOM	RANDOM
edotru	cbpsxz	hmfbk	fsxwlg	DETOUR	DEVOUR
atliro	qhcxzp	ujckgm	ynxezk	TAILOR	SAILOR
imdlwe	ybugko	zhjtop	ysjvqc	MILDEW	MILDER
uoltwa	gdipzh	xgmifp	ifbpsj	OUTLAW	OUTLAY
rwaeht	pxsjvk	fxqcuo	qysonm	WREATH	BREATH
ocvnxe	bzqtrg	qhaur	dklgjw	CONVEX	CONVEY

Nonword Trials					
nauo	zykplq	igtykw	qgpydc	ANOUSE	AROUSE
neicgn	axlroh	rlqwhu	prwavz	ENCING	ENDING
rartla	fgcqpn	mguqfo	pbdkzi	ARTRAL	ASTRAL
acines	trvqxu	xturlw	bugplk	CANISE	CANINE
eblasm	ohudjt	tunxov	zgyxkf	BEALMS	REALMS
uckcno	rflmxi	lftbri	tlhfgx	CUCKON	CUCKOO
lbaesk	wcfoqy	gctyxh	hvdwoy	BLEAKS	BREAKS
lfbiel	pzdum	txpkan	mzdqts	FLIBLE	FOIBLE
lsiu	hdrkqx	ofmgrx	bpfojq	SLUISE	SLUICE
acbrl	hytwqd	oxuisd	gqvzxf	CARBLE	MARBLE
achmt	bwjxvz	igxsyd	dwjynx	CAMHET	CACHET
hctahc	yenjyb	birzmy	ubyjse	CHATCH	THATCH
hcsist	wnvqjp	bgofnq	paqlbx	CHISTS	CHESTS
lctahc	wydbiv	fdviqy	jbzyde	CLATCH	CLUTCH
lclsd	fmwzgx	nwzhfv	kqebtf	CLOLDS	CLOUDS
octaeh	fqkidn	nzivrb	nkmgbs	COATHE	LOATHE
ocaret	fbpzws	npfvjy	bhfznq	CORATE	CURATE
rtieh	npmdvu	upjqyn	qpxoma	CRITHE	WRITHE
edgnht	spuorc	aysbfp	bopxks	DENGTH	LENGTH
tenuci	fxqkmb	mszdr	wobqag	ETUNIC	ETHNIC
psnayd	vjlber	kuljzr	ulbfw	SPANDY	SHANDY
iwlasd	onmgfy	bnmyuo	obufxq	WIALDS	WIELDS
rwbose	mxytfc	gtvkjz	mtylni	WROBES	PROBES
rguas	loehqf	jcehxd	wjhldx	GRAUNS	GRAINS
ivkcy	garoqz	splrqj	uldjrq	VICKEY	MICKEY
ojtnsh	wueabx	rzdplw	kduyax	JONTHS	MONTHS
elopst	ciyznh	hakxrn	yfvcz	LEPOTS	DEPOTS
afazdr	ptuqcv	ugqpxw	xcnjyi	FAZARD	HAZARD
amonsp	zfxtbw	czfehk	viyhue	MANOPS	MANORS
omtryh	iupvfj	ljvasi	njkucv	MORTHY	WORTHY
anansl	juvhti	djxifp	xjduhp	NANALS	CANALS
enivel	duxyza	jucbyf	kumdtg	NEVILE	REVILE
apmrht	iknzuo	ixukvo	bid sno	PARMTH	WARMTH
emidhs	jcgabr	tpjfcv	xcjyvl	MEDISH	MODISH
psyadi	bvrfmh	ofqmtn	nkjwrb	SPAYID	SPAYED
lpraec	kwfjns	mxuqjn	ydxjvh	PLARCE	PLAICE
omksyl	vgxbrp	enpgaw	xjefpi	MOSKLY	MOSTLY
oprust	jfahge	dgaejm	ebvqdw	POURTS	COURTS
rpuohc	yvstna	jqbswm	zestaw	PROUCH	CROUCH
httos	jivbqf	ljrbvm	qgkvwy	THOTOS	PHOTOS
erases	hyngqk	bntgyo	xgcyuk	RESAPE	RESALE
arptel	cdsjih	nucvbj	giqown	RATPLE	RATTLE

uminyn	zcwbfk	jwkscx	xzgsbe	MUNINY	MUTINY
csarsc	imleqd	gefjuw	ydqhtb	SCRACS	SCRAPS
hsirts	bklye	xgqleb	ovejgk	SHRIST	SHRIFT
wsdire	khvqnj	cuxobq	mgntaq	SWIDER	SPIDER
psniti	ehjcqd	jwfxqg	mxflcw	SPINIT	SPIRIT
psilsb	fcqxgh	cgmawj	uodmac	SPLIBS	SPLITS
qseule	vtwgnp	gonhkd	xymonb	SQUEEL	SQUEAL
qsiuev	fkybwn	hlopgy	byakop	SQUIVE	SQUIRE
tsraeg	qwjmuh	mifjnl	fynuhb	STARGE	STARVE
tseeyk	jcfbrv	bfzwhx	pomxwq	STEEKY	STEELY
nuisep	dahcyx	jkxhbx	azgbwc	UNSIPE	UNRIPE
tocael	wvshyn	vbgnpq	jhfisyx	OTACLE	ORACLE
avkwde	ixyjsq	ronfmq	sqmpty	VAWKED	HAWKED
ejtrxe	hcvukp	npblgu	qlhnzg	JERTEX	AERTEX
rwnesd	zqipqb	bfozmy	byvcig	WRENDS	TRENDS
nyhcde	pbuxwt	sjukro	urjsxv	YNCHED	INCHED
acedsm	rjkqyp	fhnrxp	bqrjvw	CADEMS	CADETS
erscli	jmybtv	mfwbdg	jdyaui	RECSIL	RECOIL
hterma	pqnycb	lnjpyq	lvfwyz	THREAM	THREAD
ufgrdi	qzxslv	pohcnq	bawlzy	FURGID	TURGID
uhgnla	ivztbx	rpevjz	wyrctj	HUNGAL	FUNGAL
uhmbti	cvnfwz	dzqvoc	koqrlx	HUBMIT	SUBMIT
ohpres	nixtjl	gualqi	vazqxm	HORPSE	CORPSE
elemna	rwfqch	pysouc	zpgyiv	LEMEAN	DEMEAN
usprde	tibmnf	bacjzv	lzskvt	SURPED	SURGED
hcwasp	nitqoj	iuvyxg	yjfvxn	CHAWPS	CHAMPS
uctsno	qdihly	wehygp	dirvqg	CUSTON	CUSTOM
hcdael	fukomz	xfiznu	nvifxp	CHADLE	CRADLE
rpmiel	wjnocx	hvqusf	dquhav	PRIMLE	PRIMLY
arnnyo	ugbjcl	kxlziw	ldehkq	RANNOY	TANNOY
erogru	qjkxha	vkwyyp	azmjkq	REGOUR	RIGOUR
aflcro	qimhkg	iusqwz	xzpdhk	FACLOR	FACTOR
imgdwe	fnrxoy	jknbhv	jzpfax	MIDGEW	MIDGET
uontya	brkmse	xkihvj	vbdkwj	OUTNAY	OUTLAY
msaeht	ruplgy	cdybpn	wyblou	SMEATH	SHEATH
ocfnwe	qvhjax	mljduv	tkuxpz	CONFEW	CONFER